EXHIBIT 3

Bilayer Resist Solutions for Sub 100nm Device Production

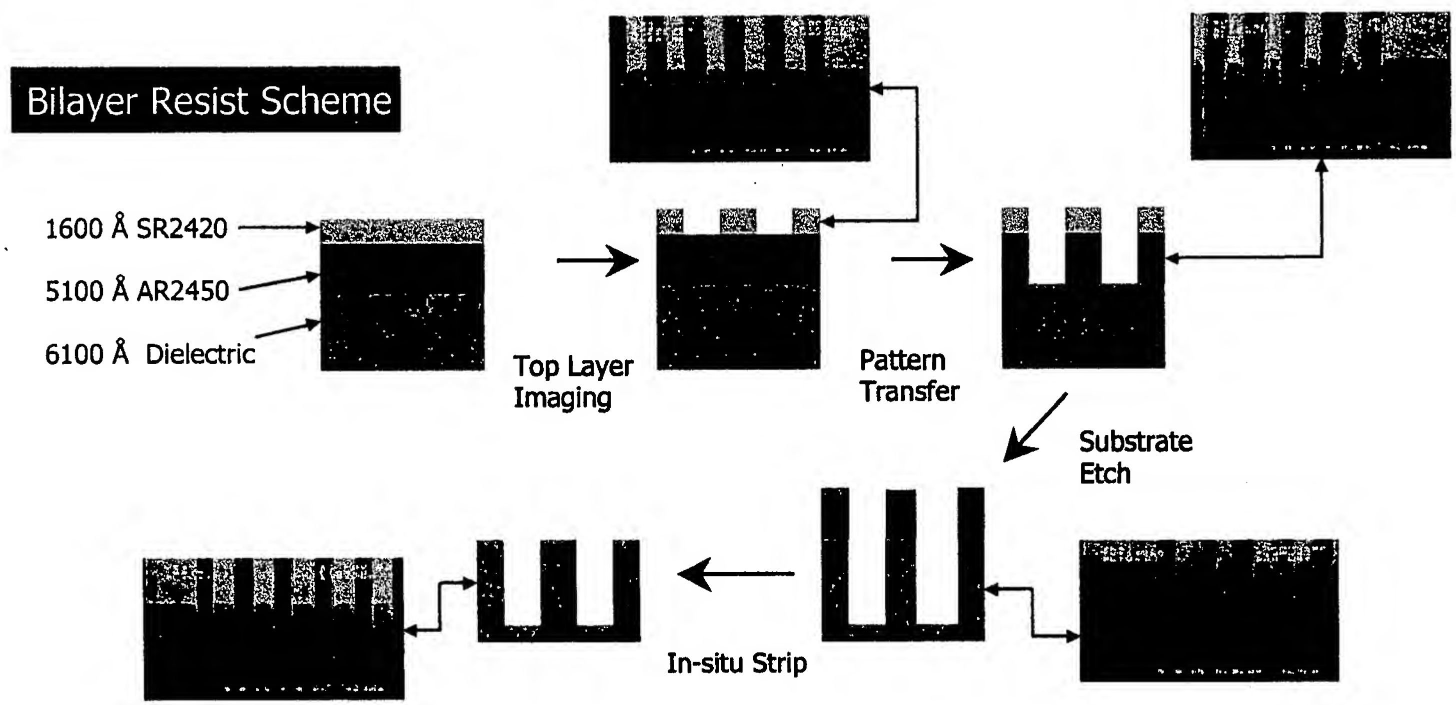
George Barclay, James Cameron, Leo Linehan, Sheri Ablaza,
Kao Xiong, Jerome Wandell, Matt King, Gerd Pohlers,
Subbareddy Kanagasabapathy and Joe Mattia

Shipley Company

SHIPLEY
A ROHM AND HAAS COMPANY

Ultra Thin Resist (UTR) Imaging

- Ultra thin imaging has potential for
  - Improved resolution
  - Process window
  - Reduced Pattern Collapse
- UTR will need an alternate etch scheme
  - Hardmask
  - Bilayer
  - Trilayer



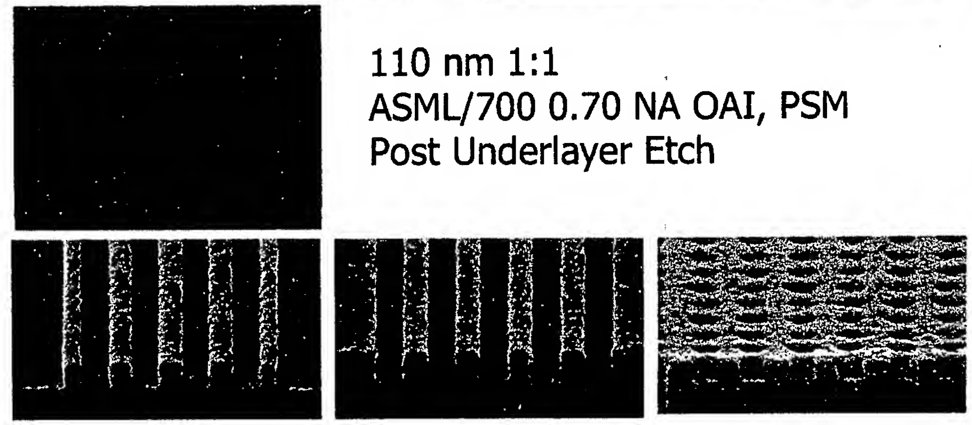
SHIPLEY
A ROHM AND HAAS COMPANY

Why Use a Si Bilayer Resist Approach ?

- ULTRA THIN RESIST
  - ➢ Improved Resolution
  - ➢ Larger Process Window
  - ➢ Reduced Pattern Collapse
  - ➢ KrF and ArF Options

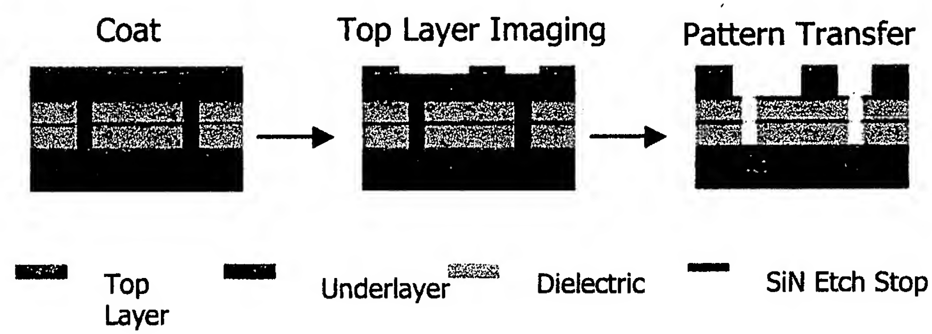
- UNDERLAYER
  - ➢ Superior Etch Resistance
  - ➢ Similar Etch Processes for KrF and ArF
  - ➢ Reflection Control
  - ➢ Planarization

- DUAL DAMASCENE LITHOGRAPHY
  - ➢ Thick Underlayer for Optimum Planarization and Reflection Control
  - ➢ Barrier to Resist Poisoning
  - ➢ Via Fill
  - ➢ Planarization over complex topographies



110 nm 1:1
ASML/700 0.70 NA OAI, PSM
Post Underlayer Etch

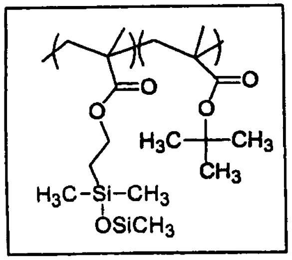
130 nm 1:1 Features:
ASML/300 0.63 NA, 6% PSM

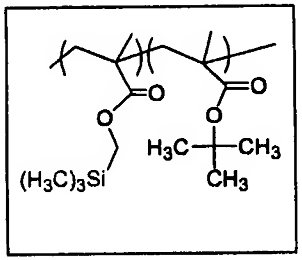


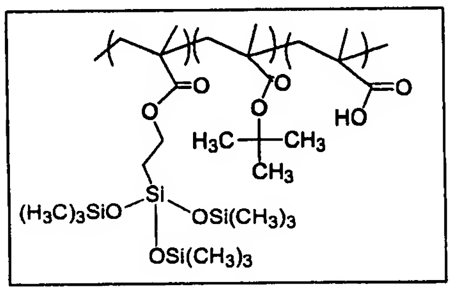
SHIPLEY
A ROHM AND HAAS COMPANY

Bilayer Resists – Silicon Polymer Approaches

➤ Pendent Silicon

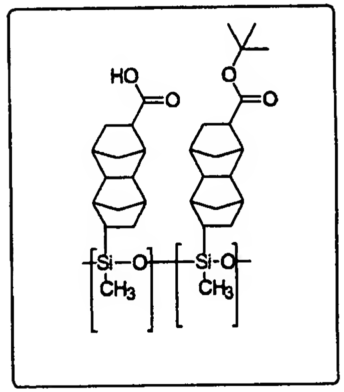






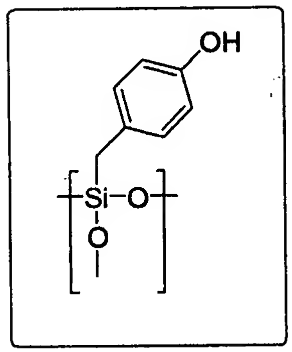
- Cornell
- IBM
- ARCH

➤ Siloxane

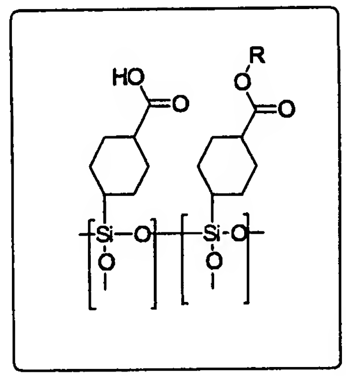


- UT Austin

➤ Silsesquioxane



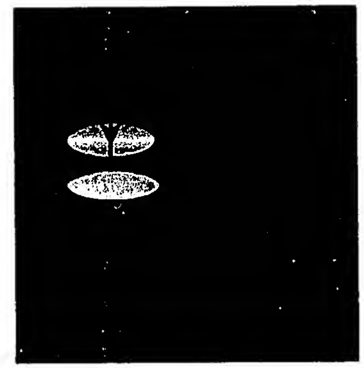
- Hitachi
- IBM



- ASET
- Shin-Etsu

SHIPLEY
A ROHM AND HAAS COMPANY

Silicon Outgassing



- Contamination of the optics with silicon has been identified as a major issue for the adoption of bilayer technology across all wavelengths
- The method of incorporating silicon into the imaging layer is important

Hien et al, SPIE 2001, Proof Plate Analysis @ 157 nm

Type	Resist [weight%]	Resist [weight%]	Proof-plate [atom%]	Proof-plate [atom%]
	Si-content	F-content	Si-content	F-content
PFA, CF_3 side chain		30		4
$PFASO_2$, CF3 side chain		26		7
Fluoropolymer		43		4
Fluoropolymer		36		2
Si main chain	16	20	0.4	10
Si main chain	12		0.6	
Polydimethylsiloxane	38		<0.2	
CH_2SiMe_3 side chain	12		3	
CH_2SiMe_3 side chain	8		6	

Table 3: XPS outgassing data for different polymers (OFI-ROM test)

Stefan Hien, Steve Angood, Domininc Ashworth, Steve Basset, Theodore Bloomstein, Kim Dean, Roderick R. Kunz, Daniel Miller, Shashikant Patel and Georgia Rich, Proceedings of SPIE Vol. 4345, 439, 2001.

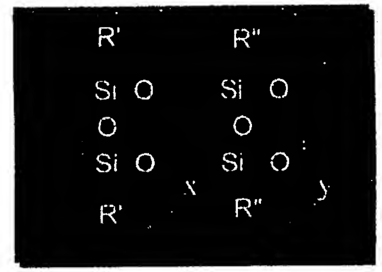
SHIPLEY
A ROHM AND HAAS COMPANY

Shipley Bilayer Resist Chemistry

- <u>Silsesquioxane Advantages</u>

- Silicon Integrated with Backbone Structure
- No Pendant Si Groups
- Very Stable Polymer
- High Silicon Content for Improved Etch
- No Outgassing of Si Species
- Only Carbon Species Observed

Silsesquioxane **(SSQ)**



SSQ Composition Study

ESCA composition		
Element	Wt%	Stdev
N	0.09	0.06
C	56.28	0.10
O	25.92	0.06
SI	14.93	0.11
S	1.30	0.05

SSQ Resist Outgassing Study

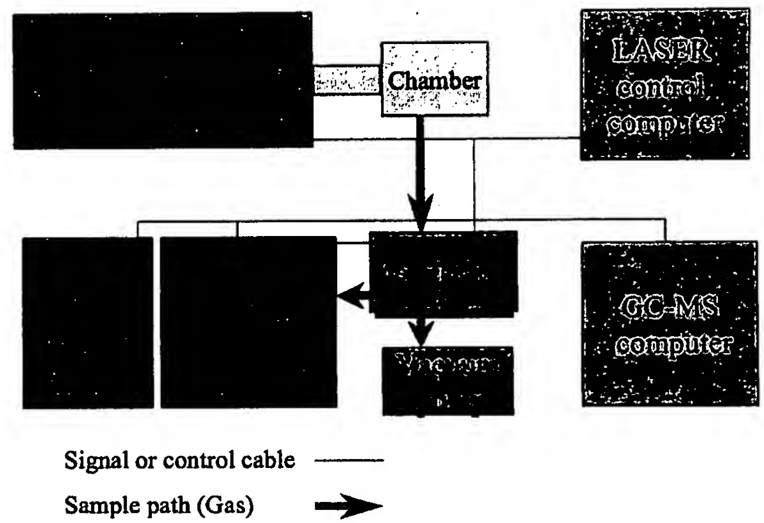
Dose	Rate	C4H8
mJ/cm2	mol/cm2-sec	
42	5.00E+12	>99.9%

No Silicon Species

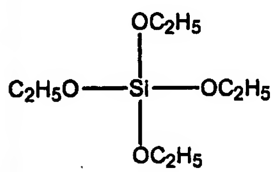
SHIPLEY
A ROHM AND HAAS COMPANY

Development of Laser Outgassing System

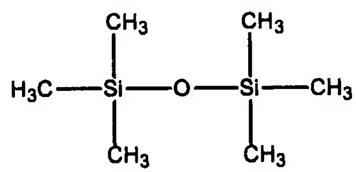
Outgassing system developed to measure the amount of volatile compounds released when exposing a material to laser radiation.



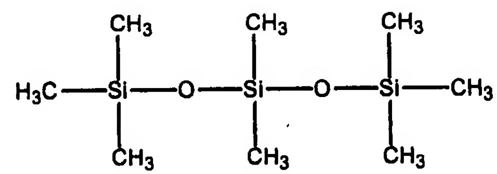
Model Silicon Compounds for Outgassing Calibration


I

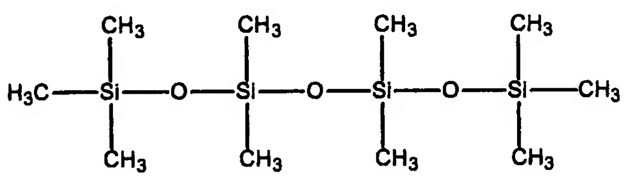
Tetraethylorthosilicate


II

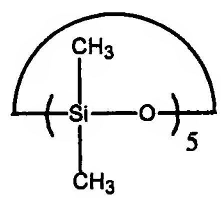
Hexamethldisiloxane


III

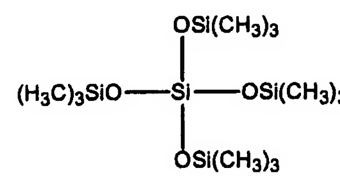
Octamethyltrisiloxane


IV

Decamethyltetrasiloxane


V

Decamethylcyclopentasiloxane

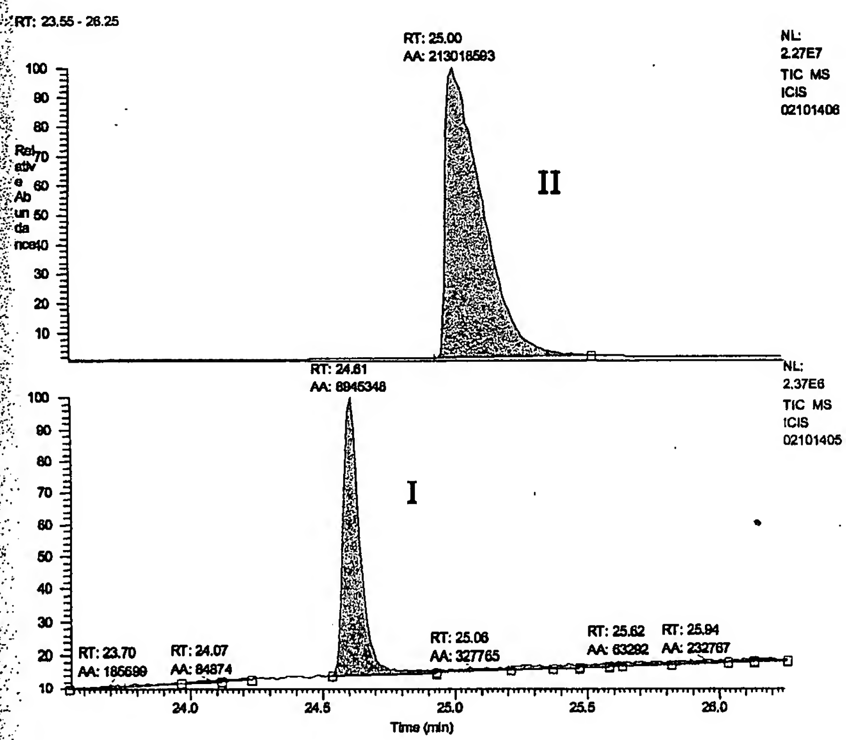

VI

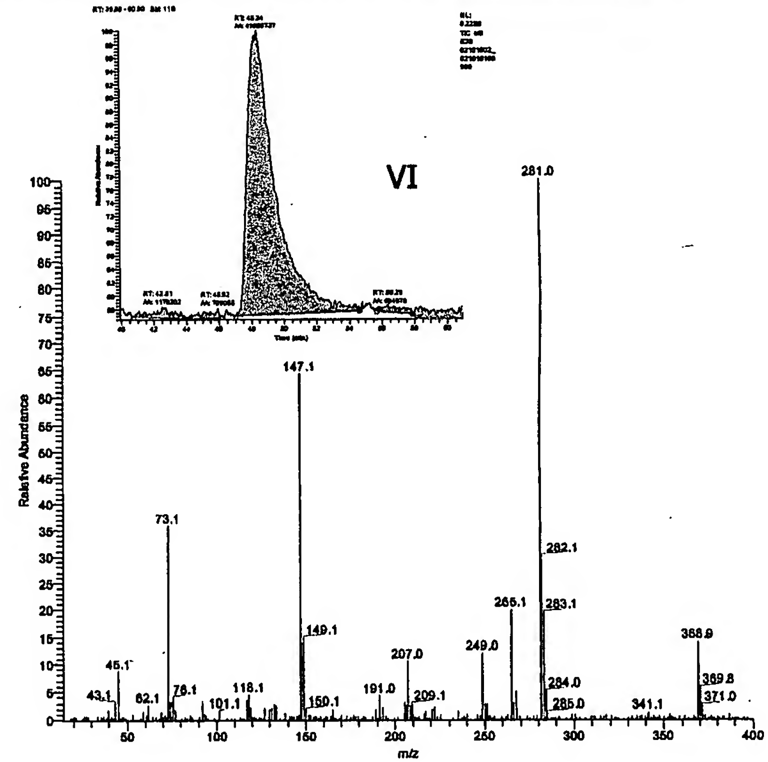
Tetrakis(trimethylsiloxy)silane

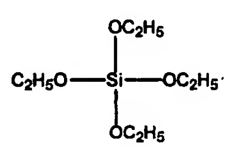
Increasing Size

SHIPLEY
A ROHM AND HAAS COMPANY

Detection of Silicon Spieces – Model Compounds

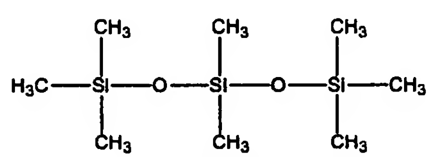






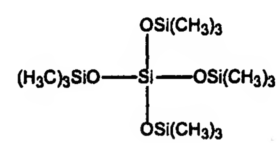
I

Tetraethylorthosilicate



III

Octamethyltrisiloxane

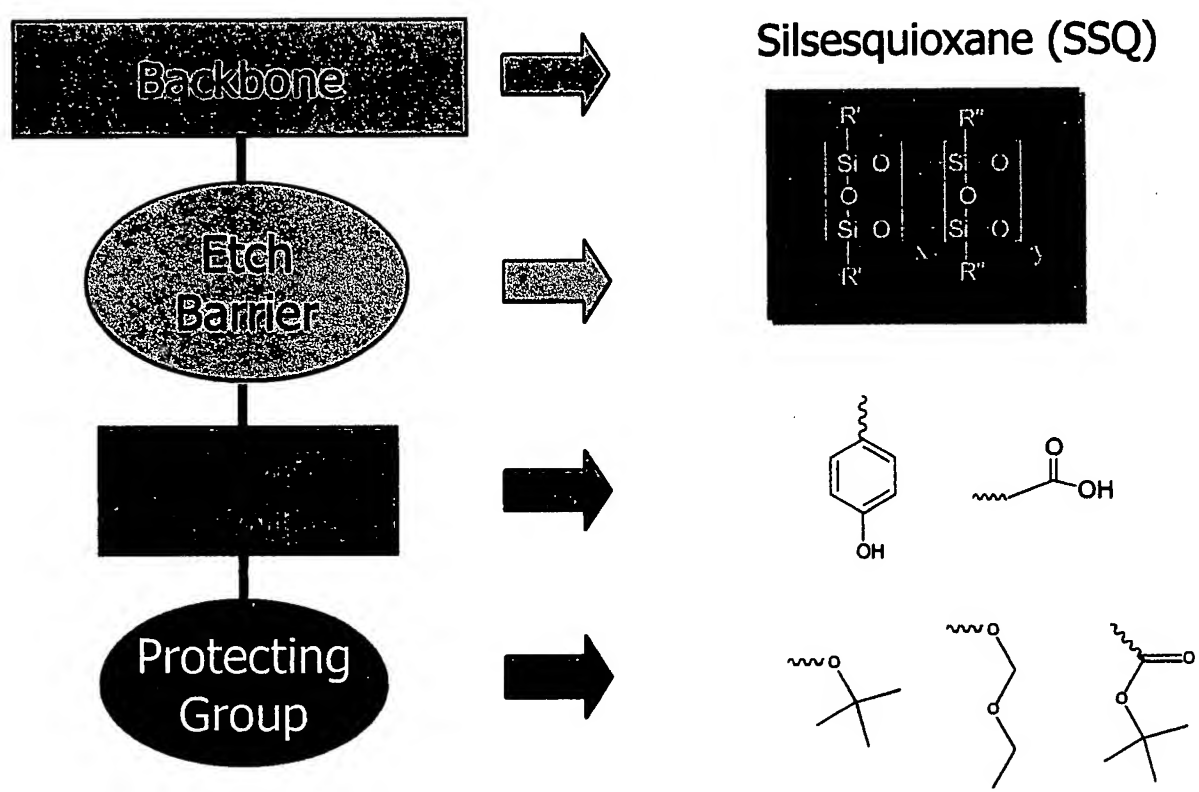


VI

Tetrakis(trimethylsiloxy)silane

SHIPLEY
A ROHM AND HAAS COMPANY

Modular Approach To Silsesquioxane Design



All modules must be transparent at the exposing wavelength

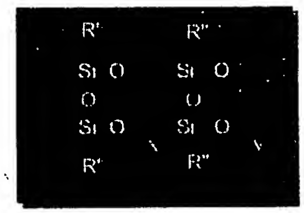
SHIPLEY
A ROHM AND HAAS COMPANY

Resist Layer: 248 Bilayer Outgassing Results

SiBER

- Silsesquioxane Polymer Approach - Advantages
  - ➢ Silicon Integrated with Backbone Structure
  - ➢ No Pendant Si Groups
  - ➢ Very Stable Polymer

Silsesquioxane (SSQ)



- No Outgassing of Si Species
- Only Carbon Species From Protecting Group Observed

Results for Outgassing Studies of XP2762A Bilayer Imaging Resist

Resist	Ambient	Dose	Rate	Isobutene	C_8H_{16} Compound
		mJ/cm^2	mol/cm^2-sec		
XP2762A	Dry N2	42	5.E+12	>99.9%	
		200	7.E+12	>99.9%	0.007%

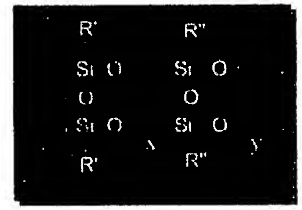
Note: Typical Outgassing Rate of Volatile Organics from DUV Resists is 10^{11} to 10^{12} molecules/cm^2-sec
Method: Flood exposure of 10 cm^2 area on coated wafer; GC-MS Analysis of concentrated headspace

SHIPLEY
A ROHM AND HAAS COMPANY

193nm Bilayer Outgassing Results: XP1646 vs UV6

SiBER

Silsesquioxane (SSQ)



- **Silsesquioxane Polymer Approach - Advantages**
  - Silicon Integrated with Backbone Structure
  - No Pendant Si Groups
  - High Si Content
  - No Outgassing of Si Species
  - Only Carbon Species From Protecting Group and PAG Observed

Laser Outgassing		Exposed area (cm2):	19.8	Datafile	
193 nm	Molecules/cm2	Chamber Volume (ml):	2000	XP1646 Bilayer 0.46 mJ/cm2/pulse 9 mJ/cm2	UV-6 0.46 mJ/cm2/pulse 9 mJ/cm2
				02052904	02052906
Ret Time	Compound		Ions	430	430
10.07	aldehyde	Photoresist	29,43	4.96E+10	3.03E+11
11.06	Isobutene	Photoresist	TIC	2.01E+14	3.31E+13
12.61	Acetone	Photoresist	43,58	6.63E+10	7.28E+11
19.62	Aromatic	PAG	91		7.54E+10
10.85	Isobutane	Photoresist	39,41,43	3.49E+11	5.64E+11
13.59	2-Propanol, 2-methyl-	Photoresist	29-72	1.58E+12	1.90E+12
14.94	Aromatic	Photoresist	TIC	1.01E+14	
15.12	Aromatic	PAG	96,70,50,39	4.00E+12	
	Total outgassing rate (mol/cm2/sec)			5.13E+11	6.10E+10
	Isobutene Outgassing rate (mol/cm2/sec)			3.35E+11	5.52E+10

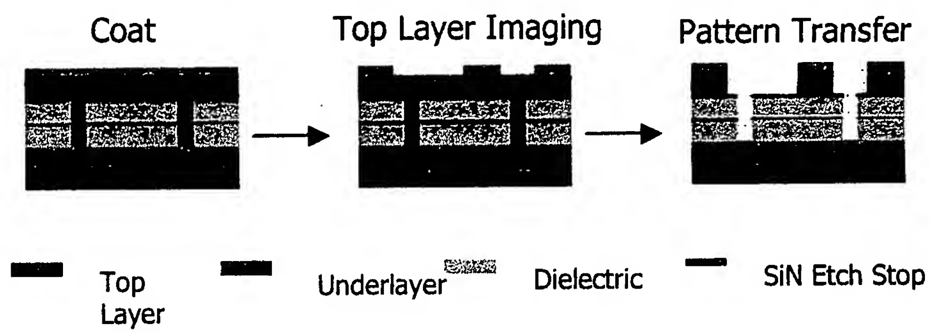
SHIPLEY
A ROHM AND HAAS COMPANY

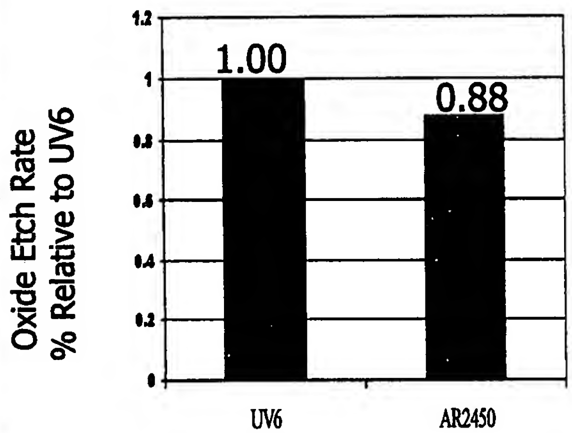
Shipley Bilayer Resist Chemistry: Underlayer Components and Performance Attributes

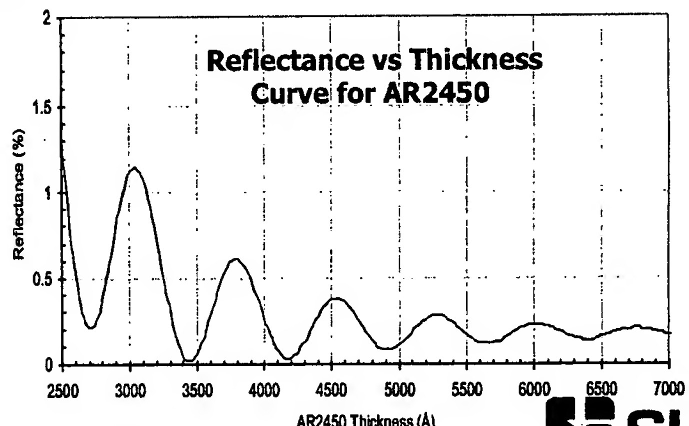
Underlayer Components:
- Etch Resistant Polymer
- Absorbing Polymeric Dye
- Thermal Acid Generator
- Crosslinker

Underlayer Performance Attributes:
- Pattern Transfer Fidelity
- Etch Resistance
- Reflection Control
- Planarization – Via Fill

110nm 1:1 LS
Post Underlayer Etch

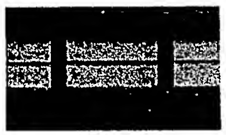






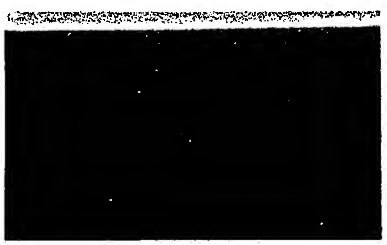
SHIPLEY
A ROHM AND HAAS COMPANY

Shipley Bilayer Resist Chemistry: Underlayer Via Fill Study



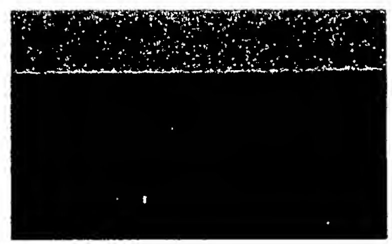
Initial Coat Thickness = 5400Å

Via Size	Via Size	Via Size	Via Size
Top = 140 nm	Top = 170 nm	Top = 320 nm	Top = 670 nm
Bottom = 0 nm	Bottom = 100 nm	Bottom = 240 nm	Bottom = 490 nm
Pitch = 360 nm	Pitch = 340 nm	Pitch = 1840 nm	Pitch = 1200 nm
Depth = 7800Å	Depth = 9060Å	Depth = 9600Å	Depth = 9740Å

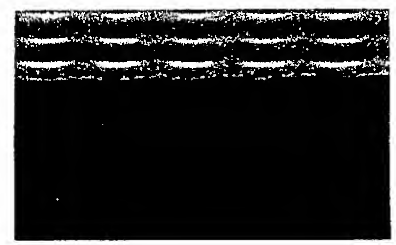


Final FT = 3960Å

Final FT = 3340Å



Final FT = 5000Å

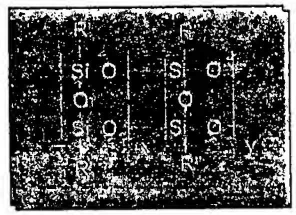


Final FT = 3100-3500Å

- Data is promising for via-fill capability at sub 130nm geometries
- No void issues for pitch values of 340nm to 1840nm
- No void issues for feature sizes of 140nm to 670nm

SHIPLEY
A ROHM AND HAAS COMPANY

Bilayer Resists for the 90nm and 65nm Nodes



KrF Bilayer

- BEOL 90nm Node
  - 140nm Contacts
  - 120nm Trench
  - Through Pitch
- FEOL 90nm Node
  - Sub 100nm LS

ArF Bilayer

- BEOL 65nm Node
  - 120-90nm Contacts
  - 100-70nm Trench
  - Through Pitch
- FEOL 65nm Node
  - Sub 70nm LS

SiBER

SHIPLEY
A ROHM AND HAAS COMPANY

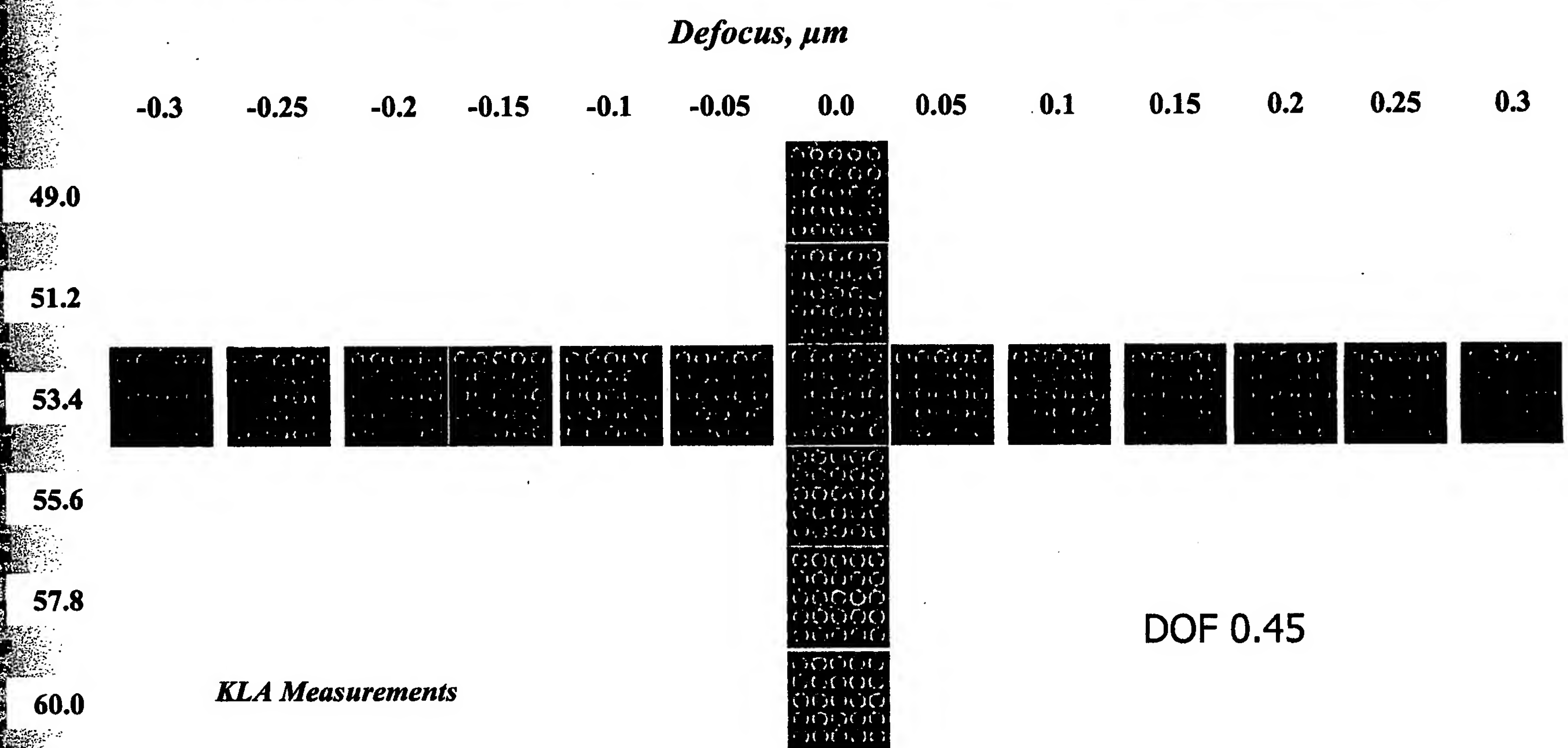
SiBER

KrF Bilayer Resists for the 90nm Node

Lithographic Performance

SHIPLEY
A ROHM AND HAAS COMPANY

KrF Bilayer: XP-0681A using 6% attenuated PSM, 0.80NA, 0.75s
Conventional 140nm/280nm +30nm Bias



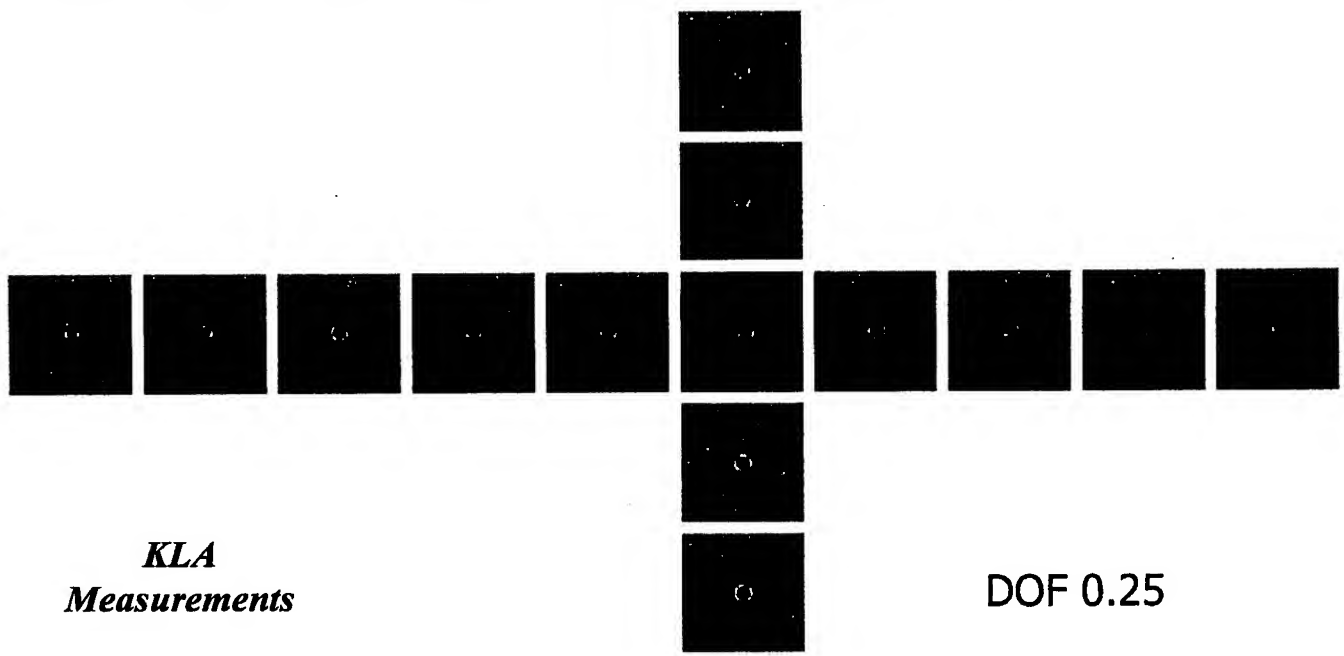
KLA Measurements

	-0.35	-0.3	-0.25	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35
49.0								124.3							
51.2								138.1							
53.4	—	107.5	131.3	128.8	140.1	137.1	141.8	141.8	142.1	142.8	131.8	127.2	112.8	110.7	—
55.6								151.8							
57.8								155.4							
60.0								163.2							

SHIPLEY
A ROHM AND HAAS COMPANY

KrF Bilayer: XP-0681A using 6% attenuated PSM, 0.80NA, 0.75s Conventional, 140nm/880nm +35nm Bias

SiBER



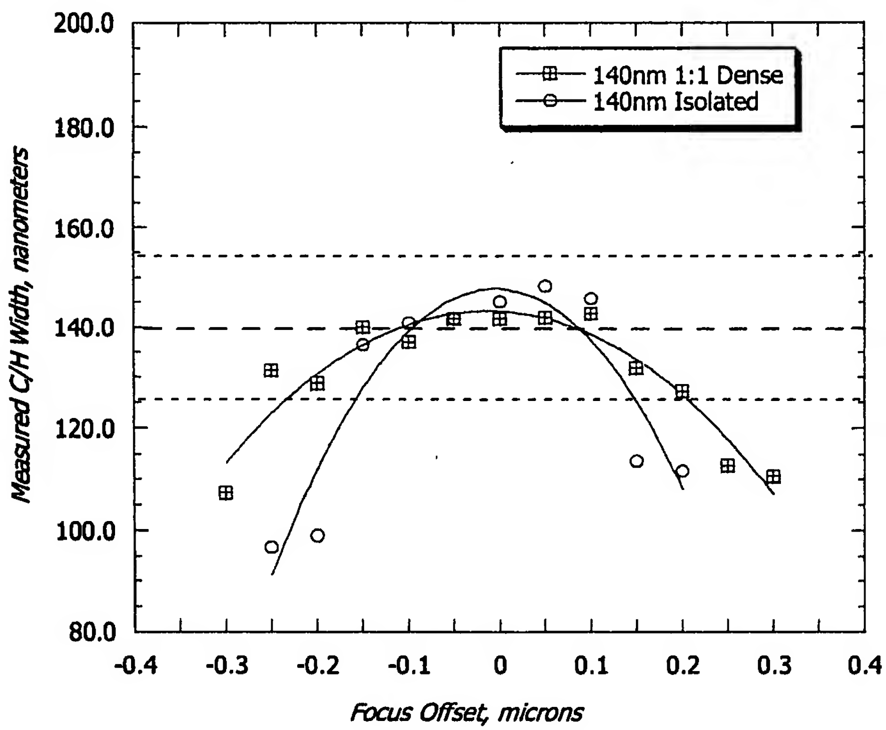
DOF 0.25

KLA Measurements

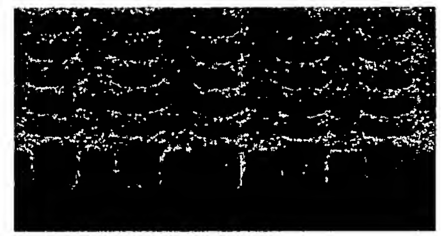
	-0.3	-0.25	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25
46.8							126.6					
49.0							135.9					
51.2							140.4					
53.4	—	96.8	99.0	136.5	141.0	141.8	145.2	148.3	145.9	113.8	111.8	—
55.6							151.9					
57.8							155.9					
60.0							166.4					

SHIPLEY
A ROHM AND HAAS COMPANY

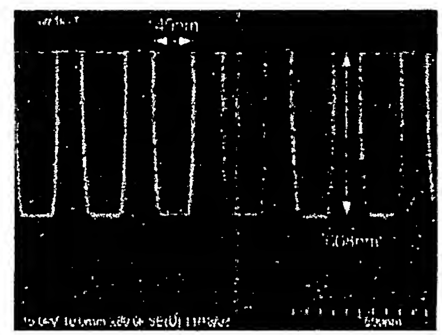
KrF Bilayer: XP-0681A using 6% attenuated PSM, 0.80NA, 0.75s Conventional, DOF Overlap 140nm Contact



XP-0681A
Overlap DOF (from plot) ~ 0.30um



140nm Contacts

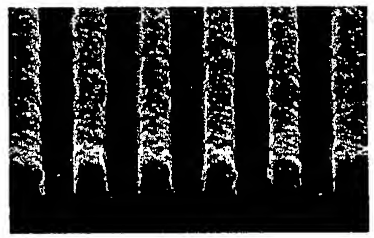


Oxide Open Etch

SHIPLEY
A ROHM AND HAAS COMPANY

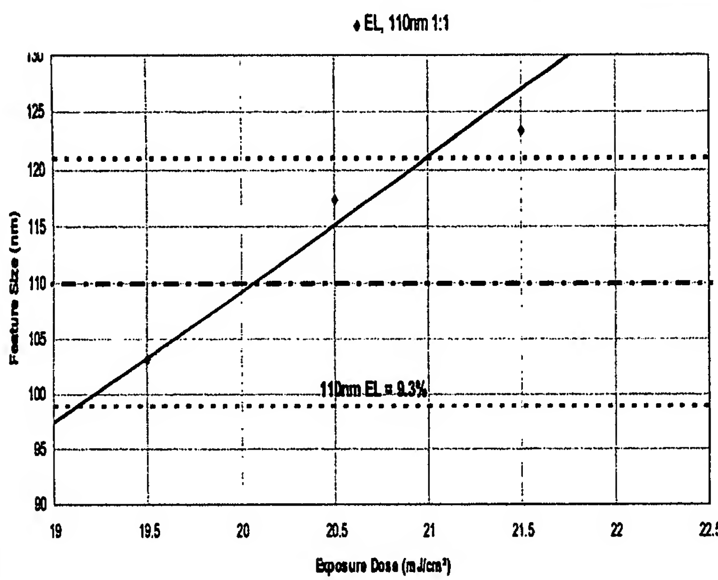
KrF Bilayer: 1400Å, SR2400 / 5100Å, AR2450
0.8NA, Annular 0.55i/0.85o, Binary, 110nm 1:1 Trench

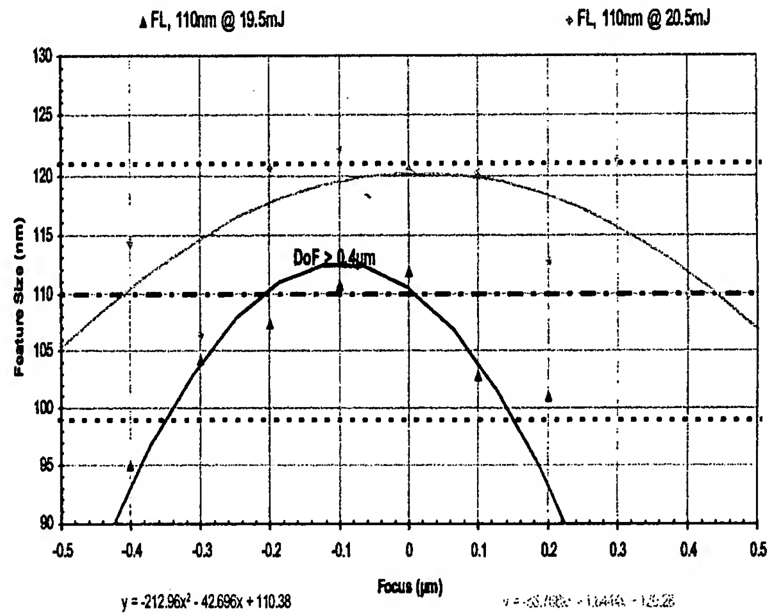
110nm 1:1 Trench



Exposure Latitude = 9.3%

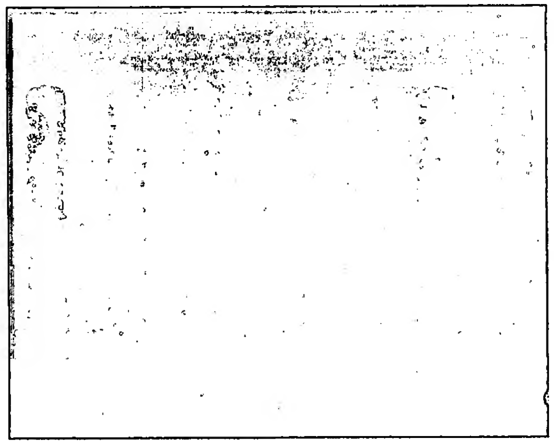
DOF > 0.40um





KrF Bilayer: Memory L/S Capability, XP2762A:6% PSM

Exposure:
ASML /700

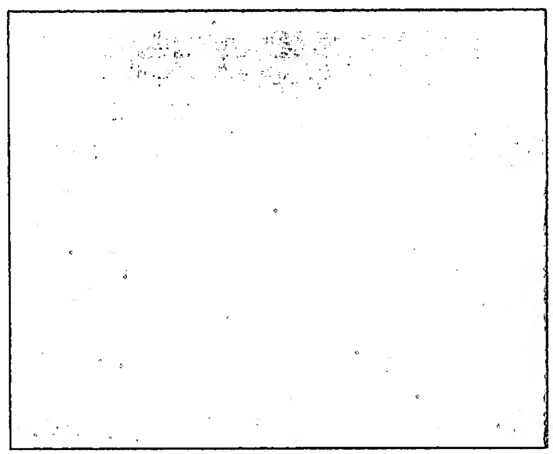


110nm
1:1 L/S

Top Layer: 1500 Å
Bottom Layer: 5100 Å

Post Underlayer Etch

Exposure:
ASML /800



85nm
1:1 L/S

Customer: "Best etch of any bilayer system evaluated"
Top to Bottom Etch Selectivity 12:1

INTEGRATING

SiBER

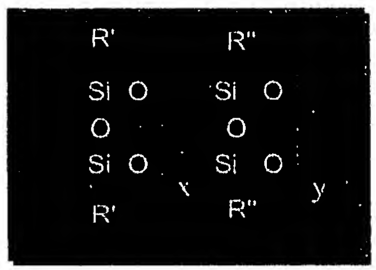
ArF Bilayer Resists for the 65nm Node

Design and Lithographic Performance

SHIPLEY
A ROHM AND HAAS COMPANY

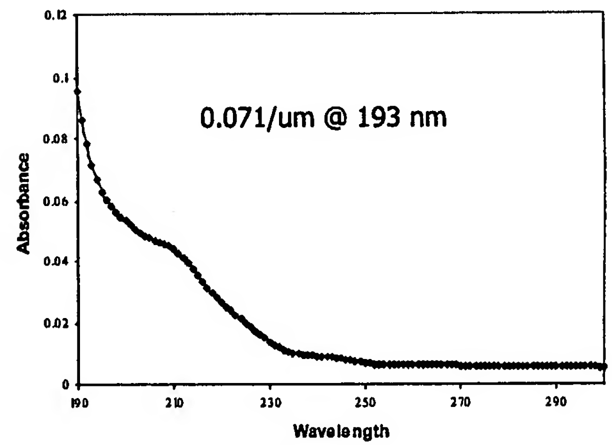
ArF Bilayer Photoresists – SR™19xx

Silsesquioxane (SSQ)

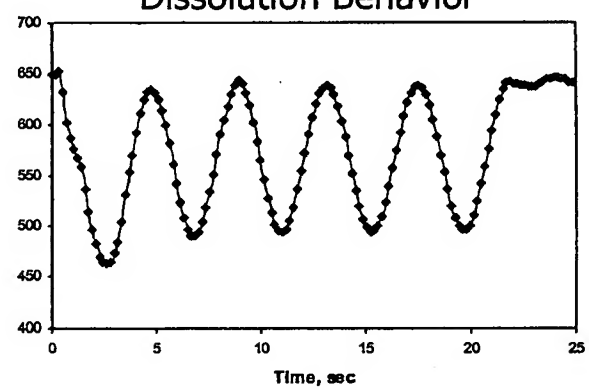


- Use SSQ backbone chemistry
  - ➢ Incorporation of high Si content
  - ➢ No Outgassing of Si species
- Pendent R Groups
  - ➢ Transparent at 193 nm
  - ➢ Dissolution Enhancing
  - ➢ Contrast Enhancing

Optical Density @ ArF



Dissolution Behavior

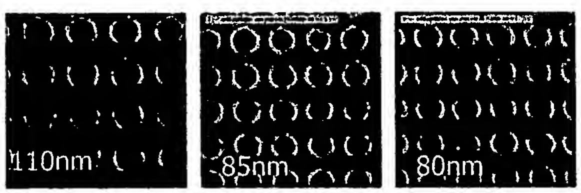


SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer Photoresists – Dissolution Contrast

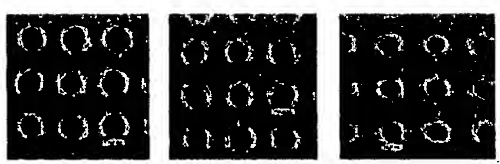
- Dissolution Contrast: Ultra Thin ArF Bilayer Resist (1000 Å)
  - ➢ Controlled by polymer design
  - ➢ Example: high contrast ArF bilayer resist for contact applications

Super Dense Contacts

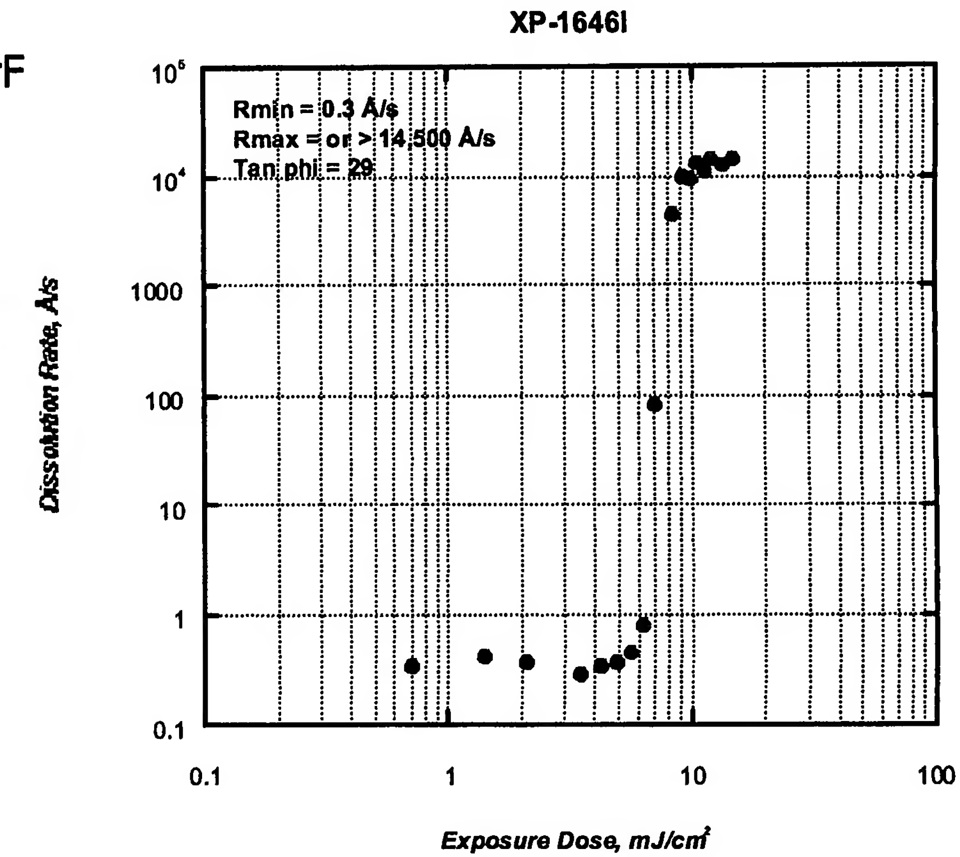


130@240 115@200 120@200

1:1 Contacts



110nm 105nm 95nm

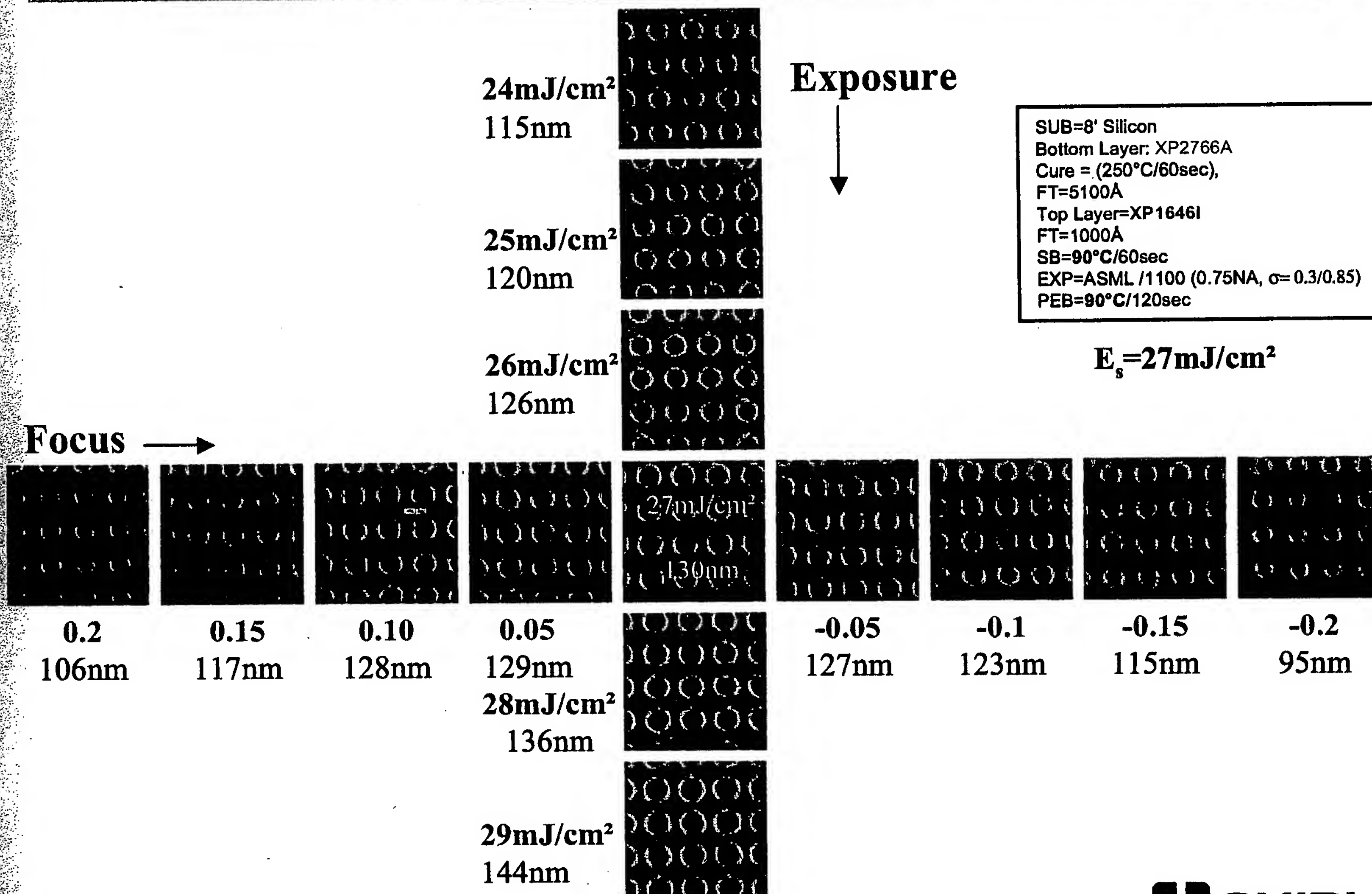


SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA
130nm C/H at 240nm pitch (direct)

SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ= 0.3/0.85)
PEB=90°C/120sec

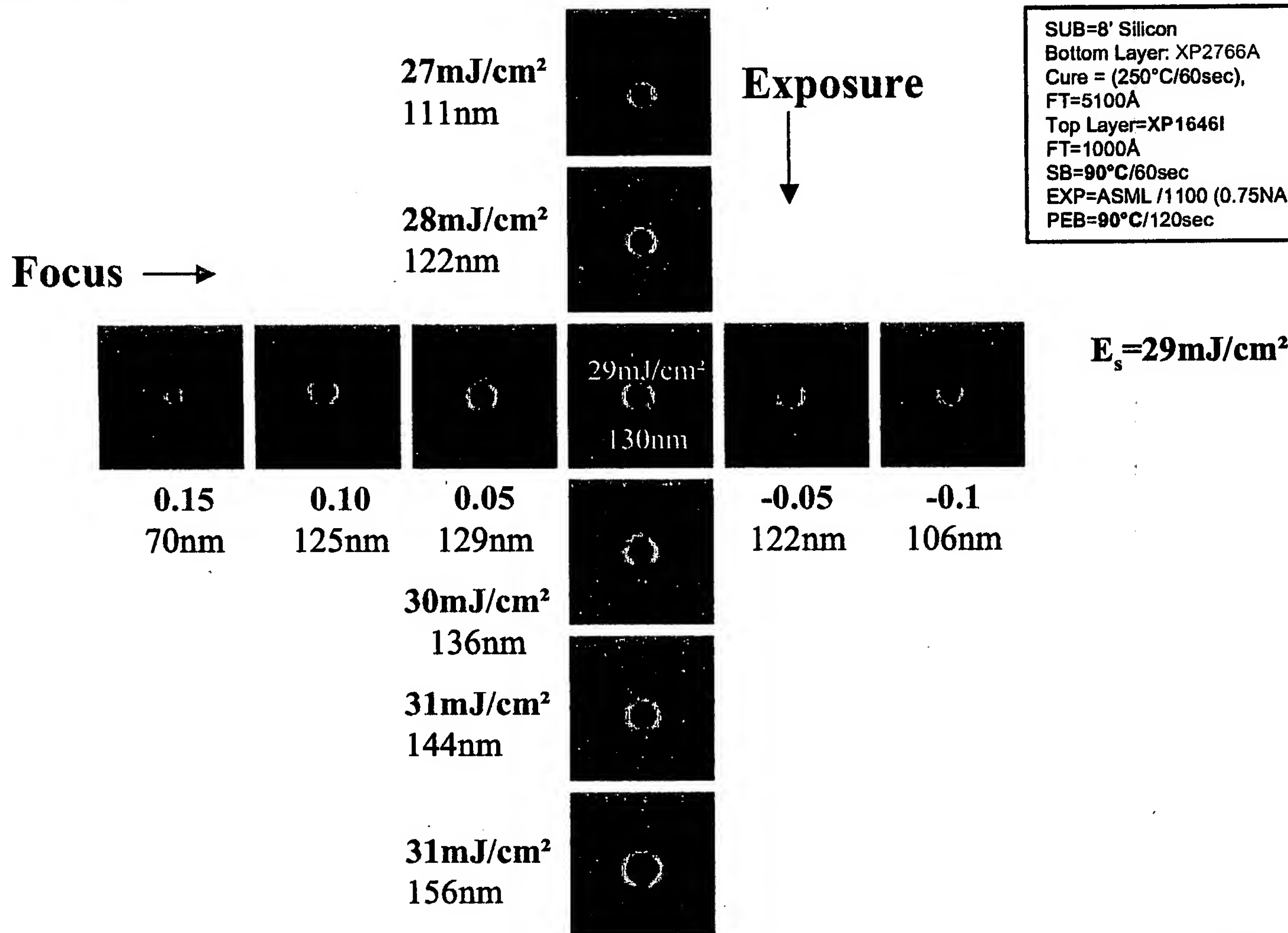
E_s=27mJ/cm²



SHIPLEY
A ROHM AND HAAS COMPANY

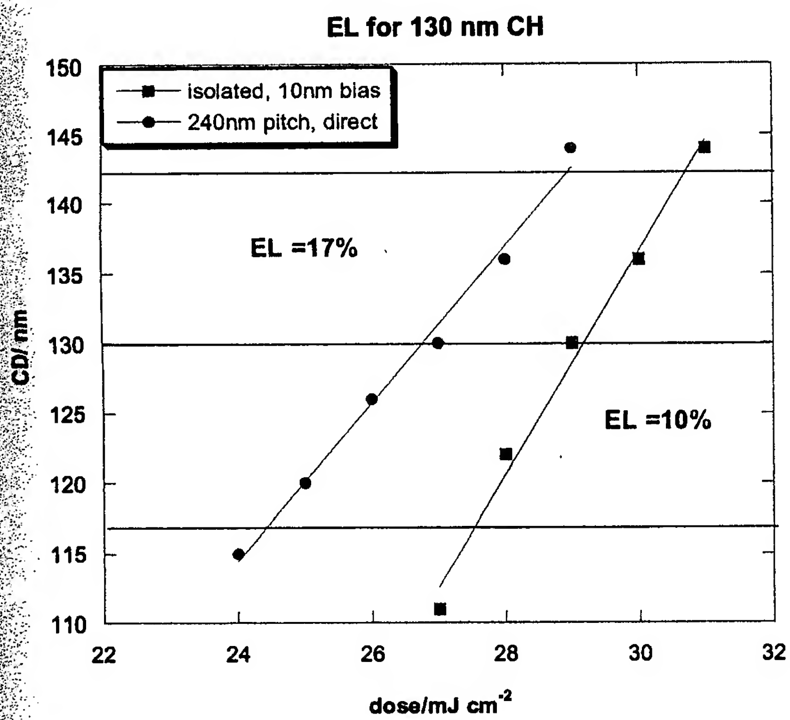
ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA Isolated 130nm C/H (10nm bias)

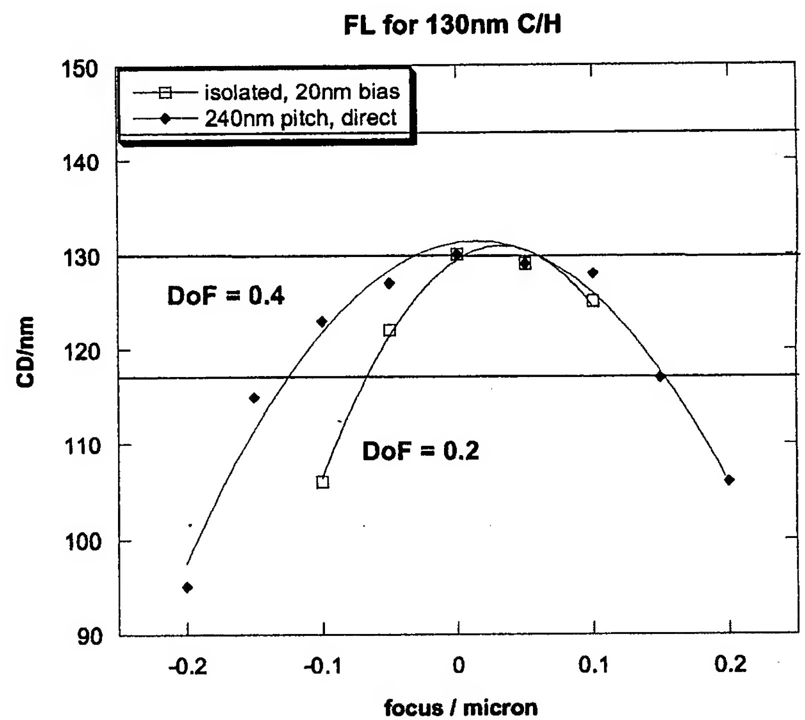
SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ= 0.3/0.85)
PEB=90°C/120sec



SHIPLEY
A ROHM AND HAAS COMPANY

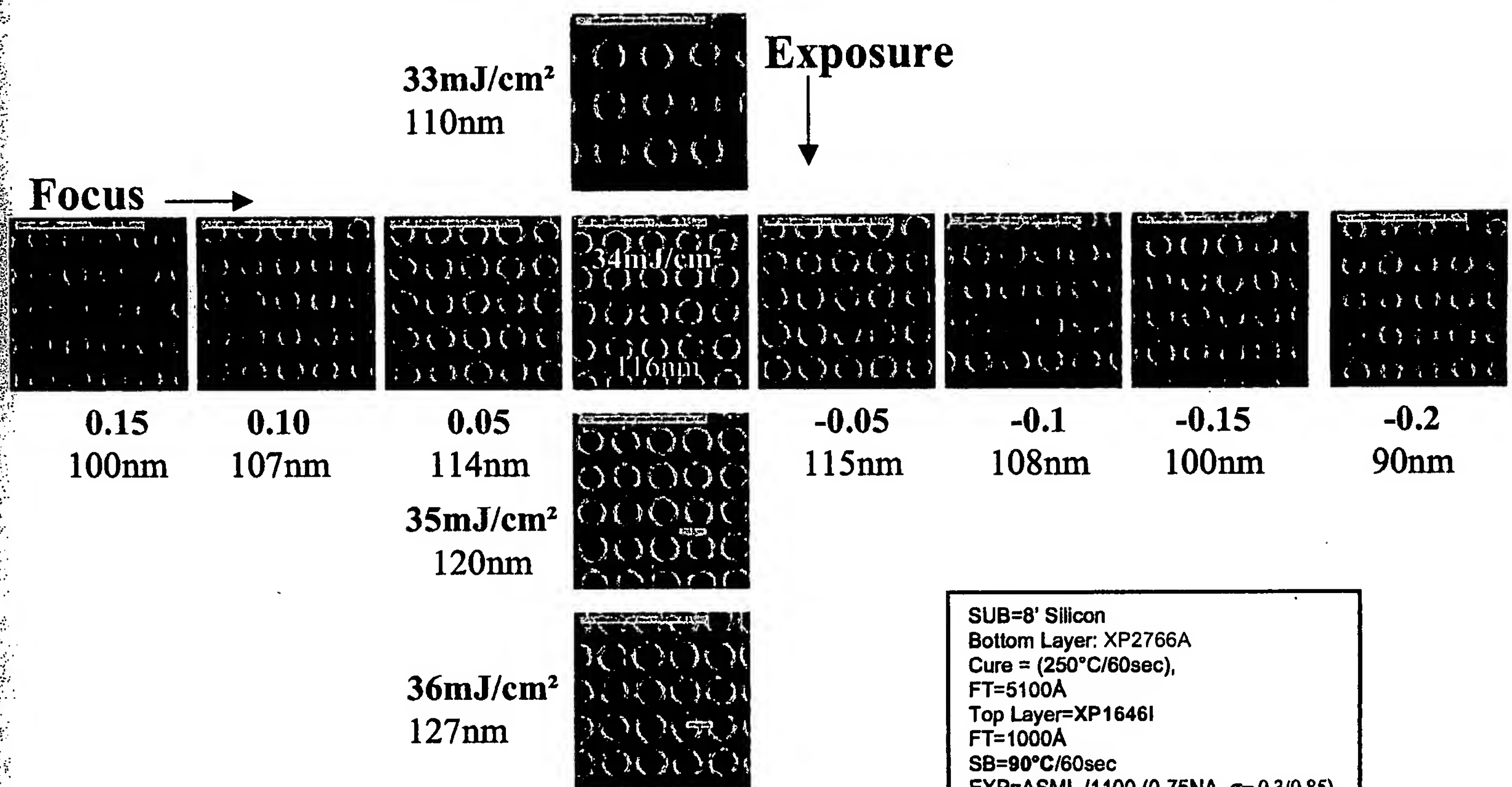
ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA 130nm C/H Super Dense and Isolated





SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA
Super Dense Contacts - 115nm C/H at 200nm pitch (direct)

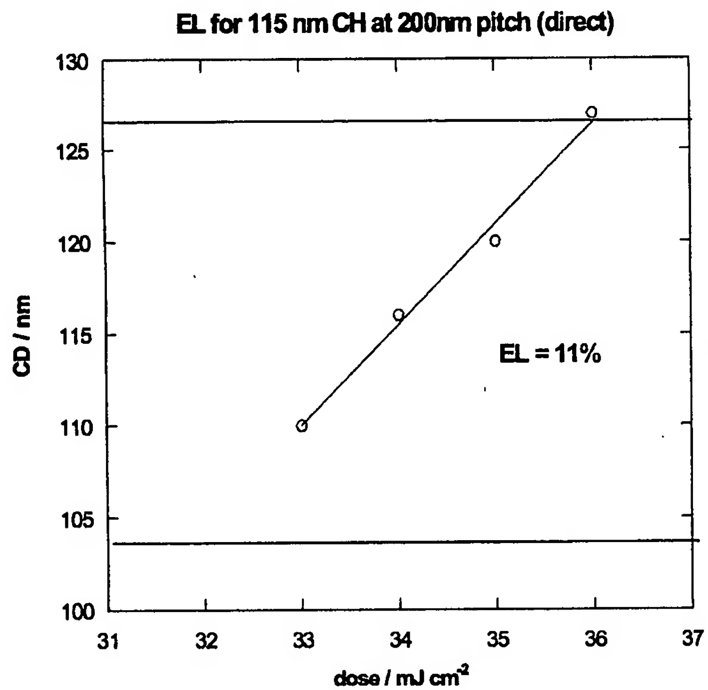


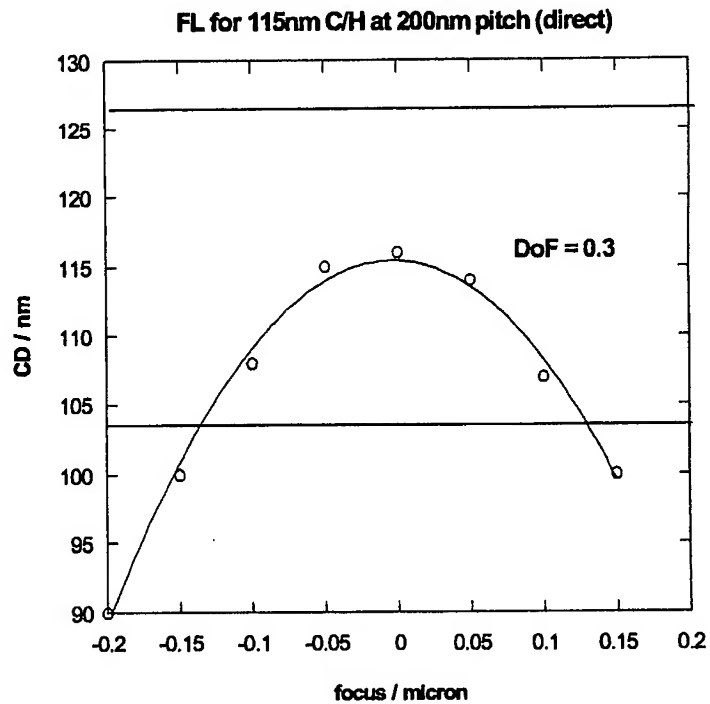
SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ= 0.3/0.85)
PEB=90°C/120sec

E_s=34mJ/cm²

SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA Super Dense Contacts - 115nm C/H at 200nm pitch (direct)

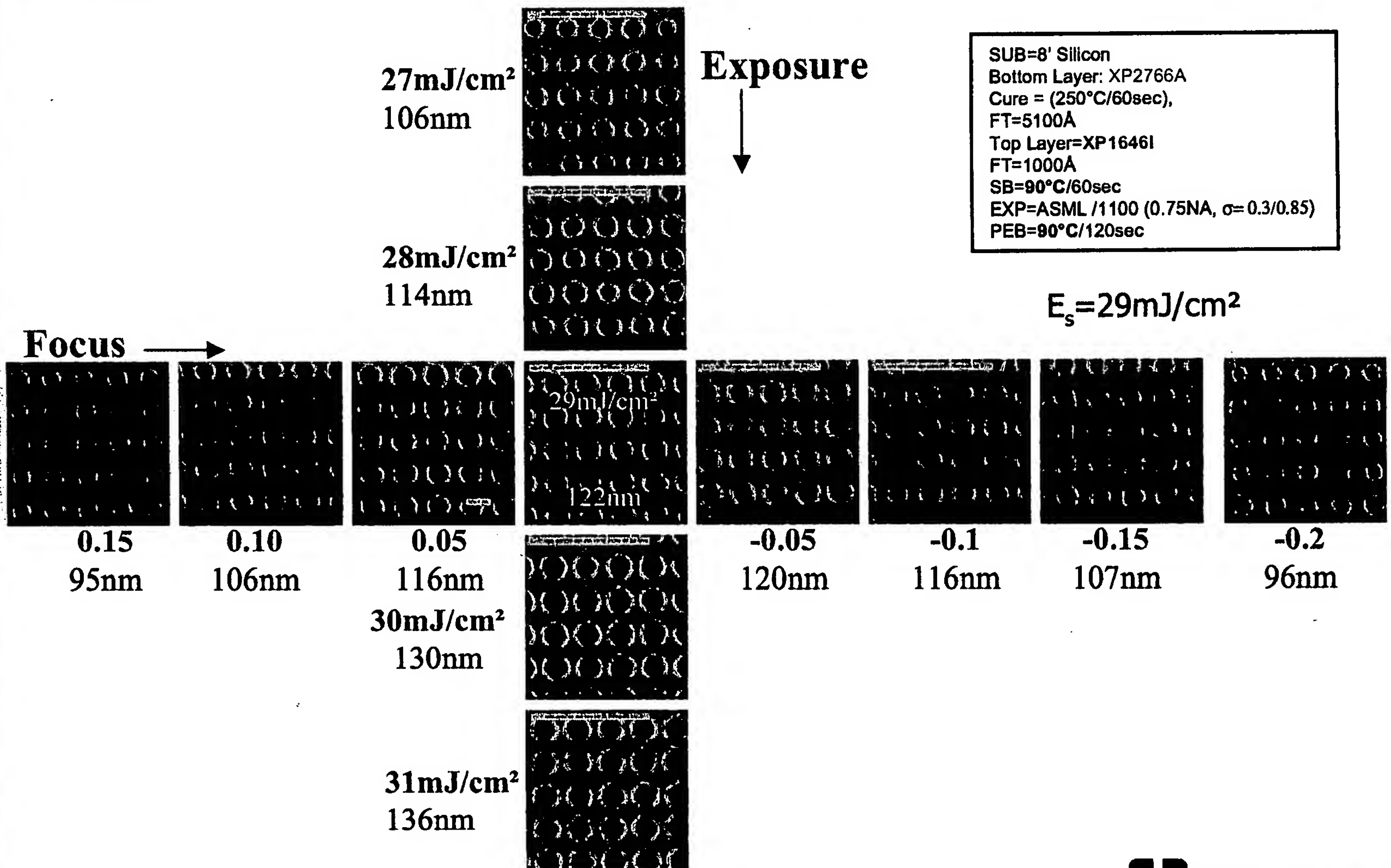




ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA
Super Dense Contacts - 120nm C/H at 200nm pitch (direct)

SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ=0.3/0.85)
PEB=90°C/120sec

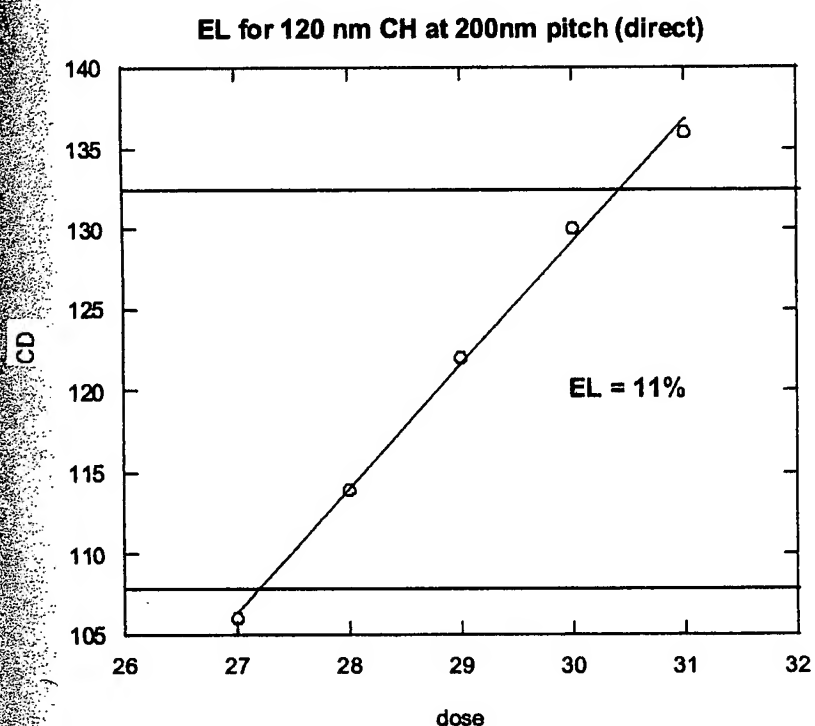
E_s=29mJ/cm^2

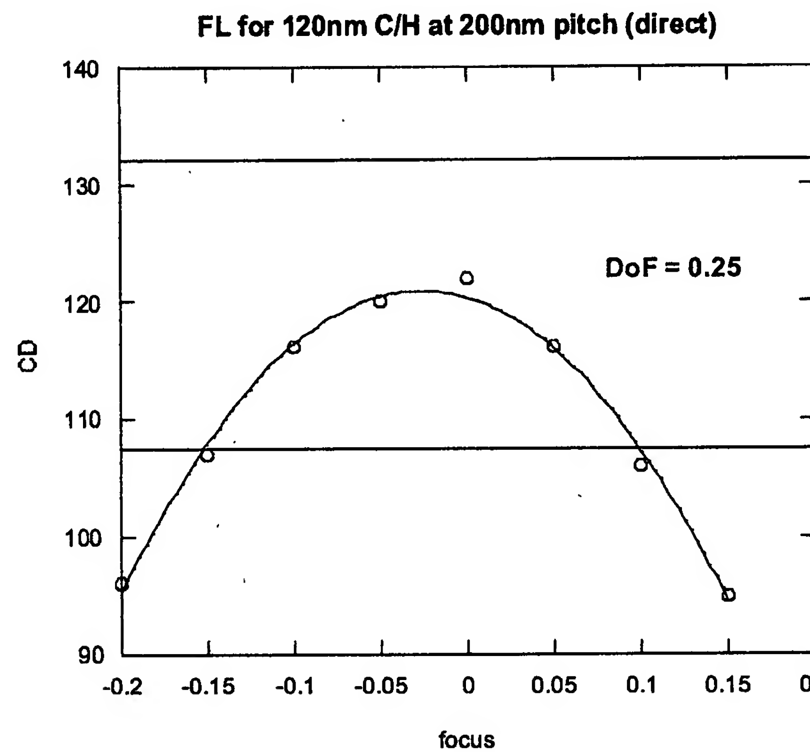


SHIPLEY
A ROHM AND HAAS COMPANY

INTEGRATING MATERIAL ADVANTAGE

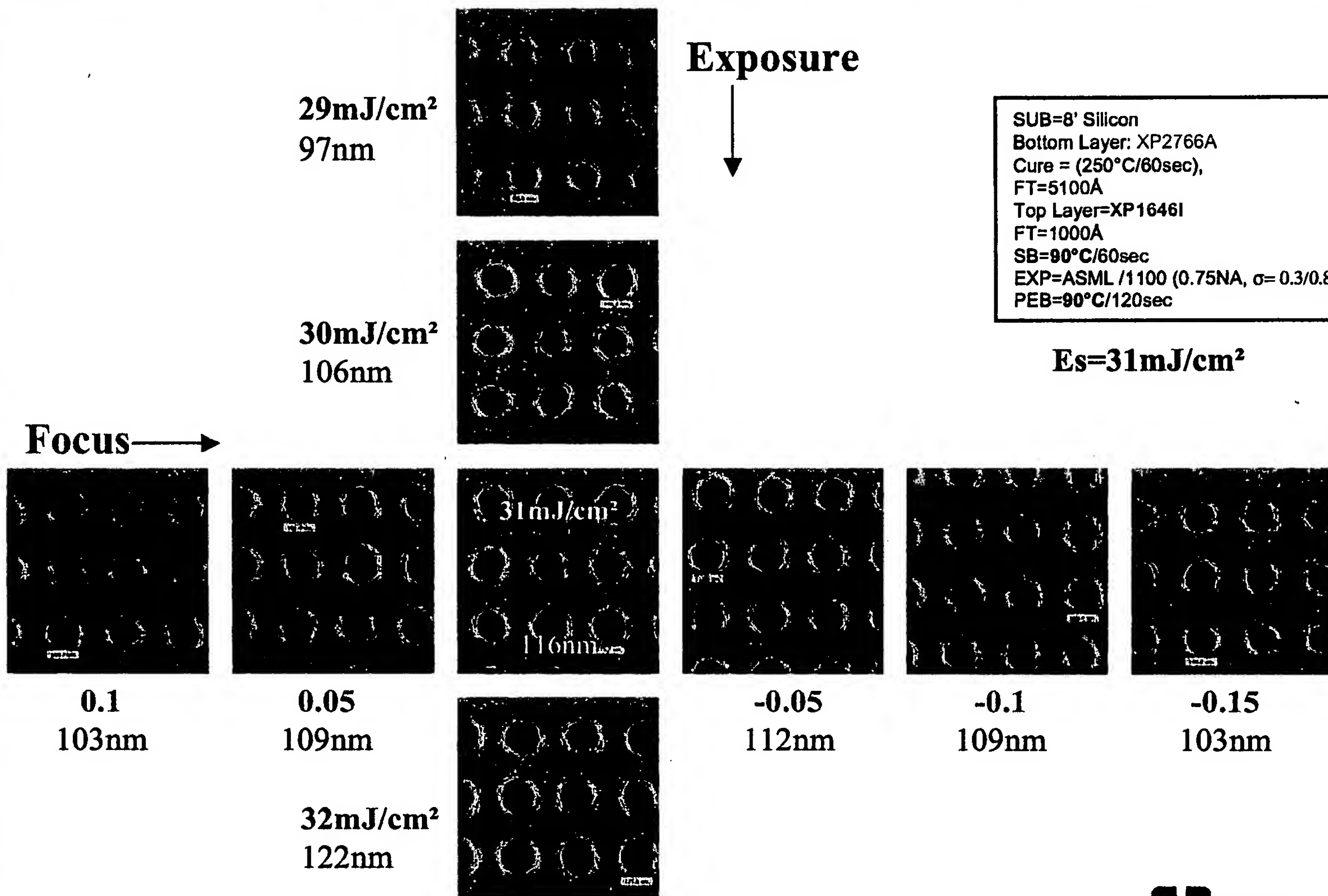
ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA
Super Dense Contacts - 120nm C/H at 200nm pitch (direct)





SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA 110nm C/H at 220nm pitch (10nm bias)



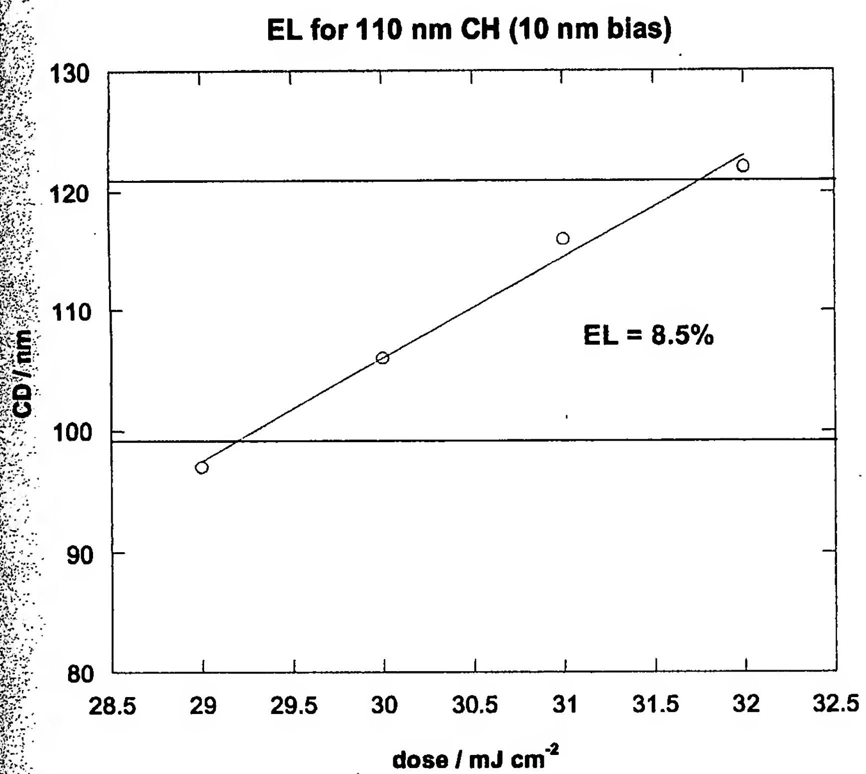
SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ= 0.3/0.85)
PEB=90°C/120sec

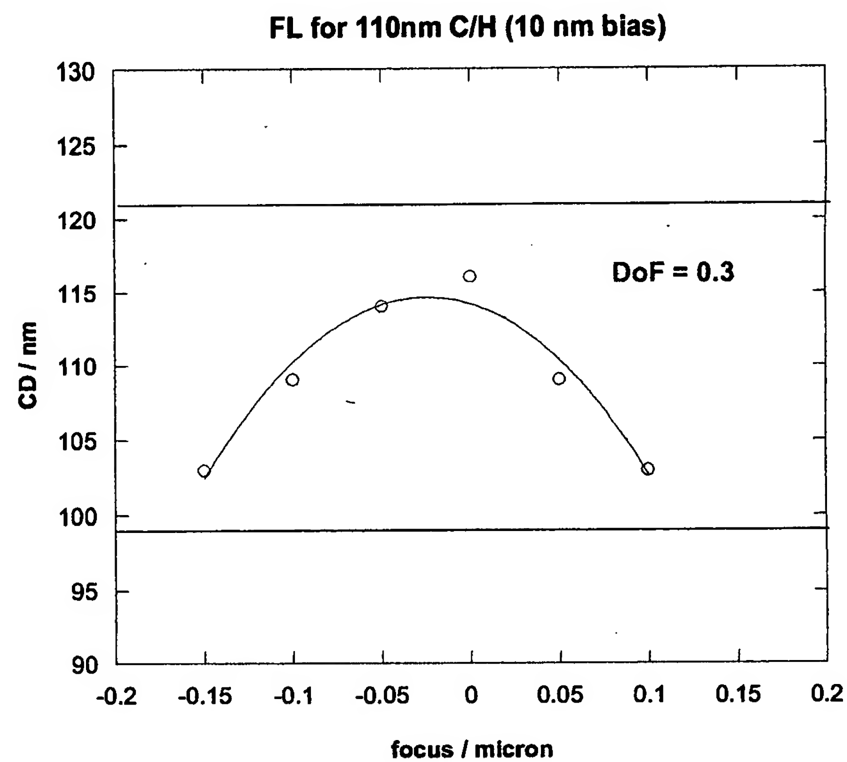
Es=31mJ/cm²

SHIPLEY
A ROHM AND HAAS COMPANY

INTEGRATING MATERIAL AD...

ArF Bilayer: XP1646I on XP2766A, using 6% attenuated PSM, 0.75NA 110nm C/H at 220nm pitch (10nm bias)





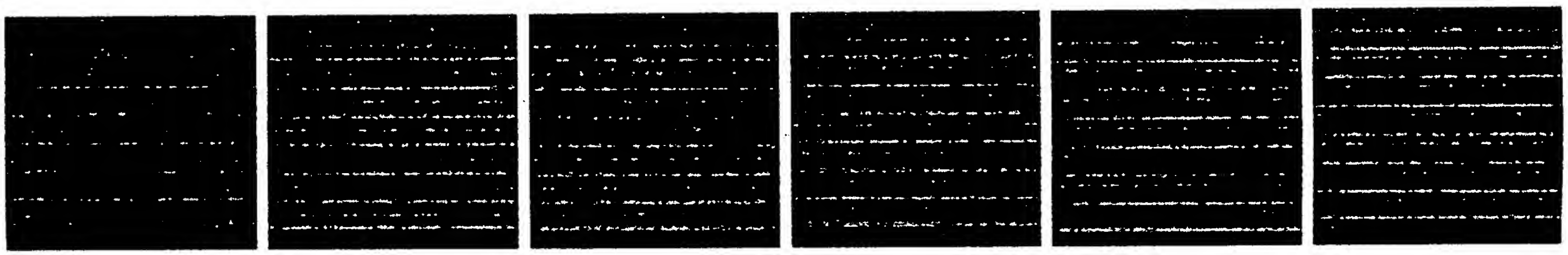
SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A (90°C / 90°C SB/PEB)
120nm at 240 Pitch and Isolated Trench (ASML /1100 Binary)

SiBER

120nm dense trench on the mask

EL



9.0 mJ/cm²	9.75 mJ/cm²	10.5 mJ/cm²	11.25 mJ/cm²	12.0 mJ/cm²	12.75 mJ/cm²
66nm	102nm	116nm	125nm	133nm	142nm

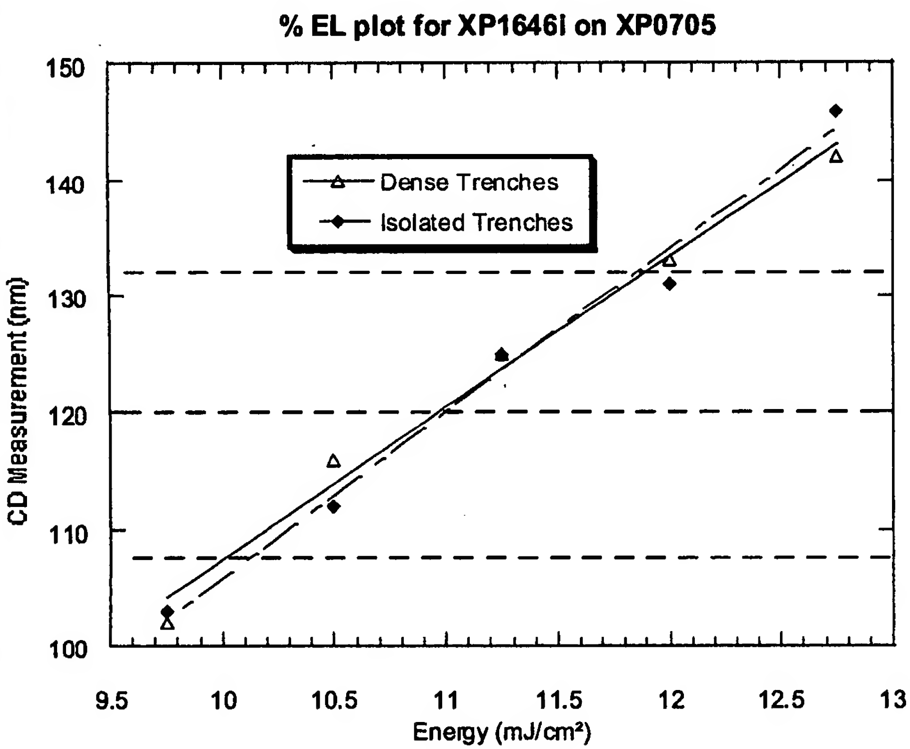
EL

9.0 mJ/cm²	9.75 mJ/cm²	10.5 mJ/cm²	11.25 mJ/cm²	12.0 mJ/cm²	12.75 mJ/cm²
81nm	103nm	112nm	125nm	131nm	146nm

120nm Isolated: 140nm on the Mask/20nm bias

SHIPLEY
A ROHM AND HAAS COMPANY

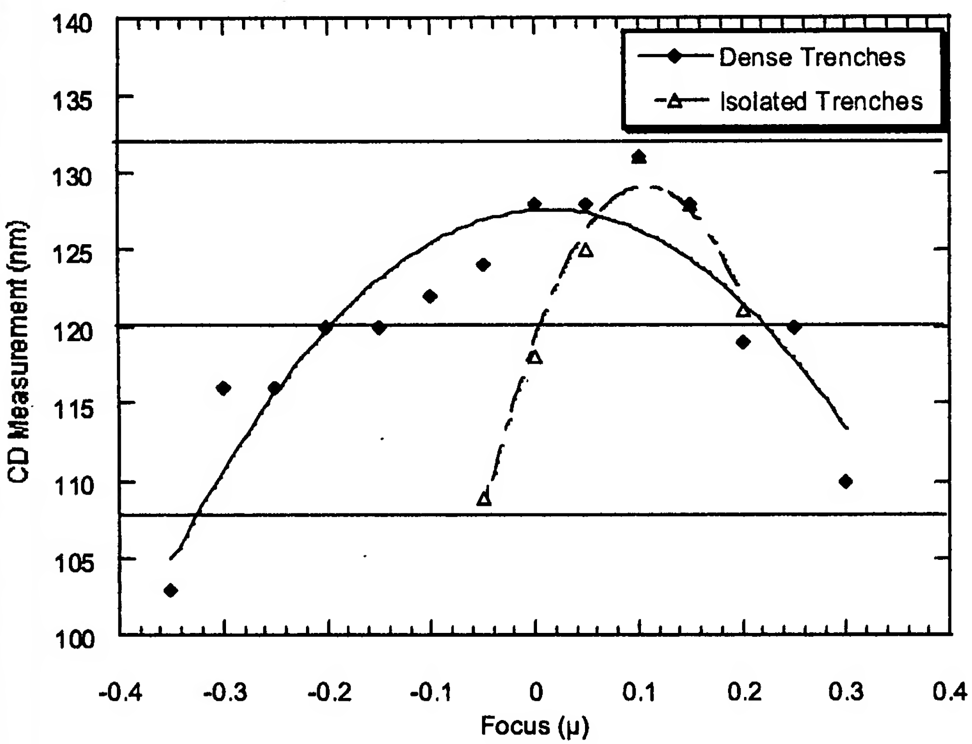
ArF Bilayer: XP1646I on XP2766A (90°C / 90°C SB/PEB)
120nm at 240 Pitch and 120nm (20nm bias) Isolated Trench

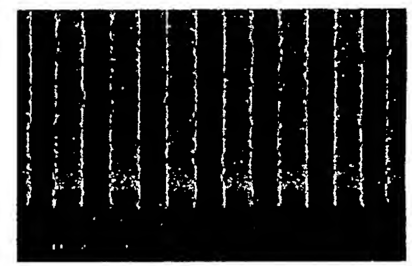


	XP1646i on XP0705 @ 90°C/90°C (SB/PEB)
Sizing Energy(mJ/cm²)	11.0
% Exposure Latitude Dense Trenches(±10% nominal)	16.9
% Exposure Latitude Isolated Trenches (±10% nominal)	15.4

SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: XP1646I on XP2766A (ASML/1100 Binary)
120nm at 240 Pitch





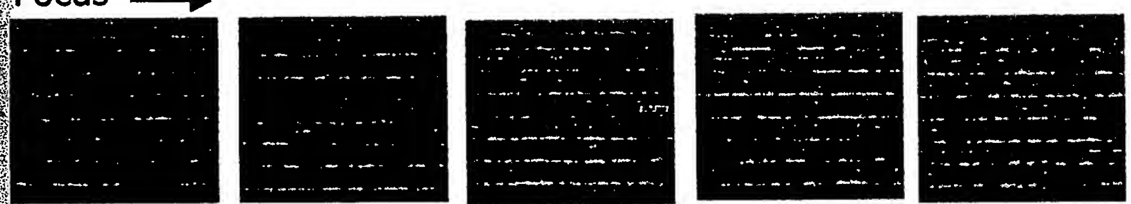
120nm @ 240 Pitch

	@ 90°C/90°C (SB/PEB)
Sizing Energy(mJ/cm²)	11.0
DOF= (±10% nominal)	0.6

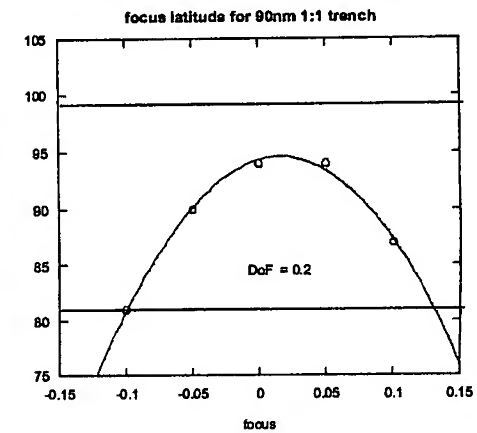
ArF Bilayer: XP1646I on XP2766A
Sub 100nm Trenches (ASML /1100 Binary)

90nm Trenches at 180nm pitch

Focus →



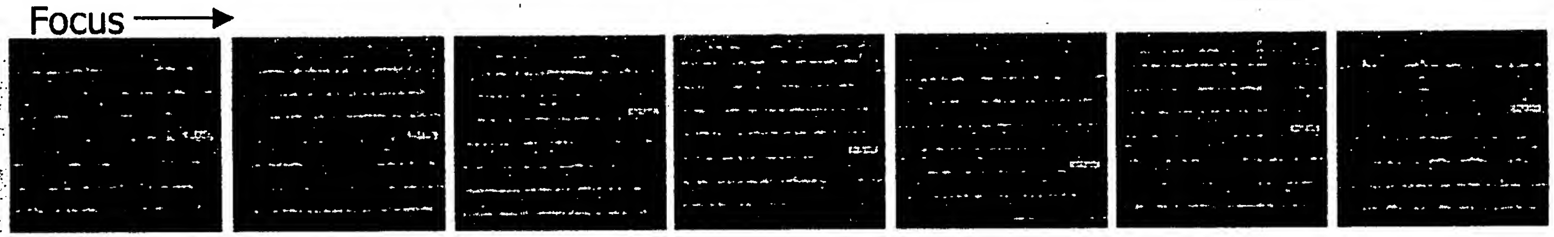
0.1	0.05	0	-0.05	-0.1
87nm	94nm	94nm	90nm	81nm



Es=18mJ/cm²

80nm Trenches at 180nm pitch

Focus →



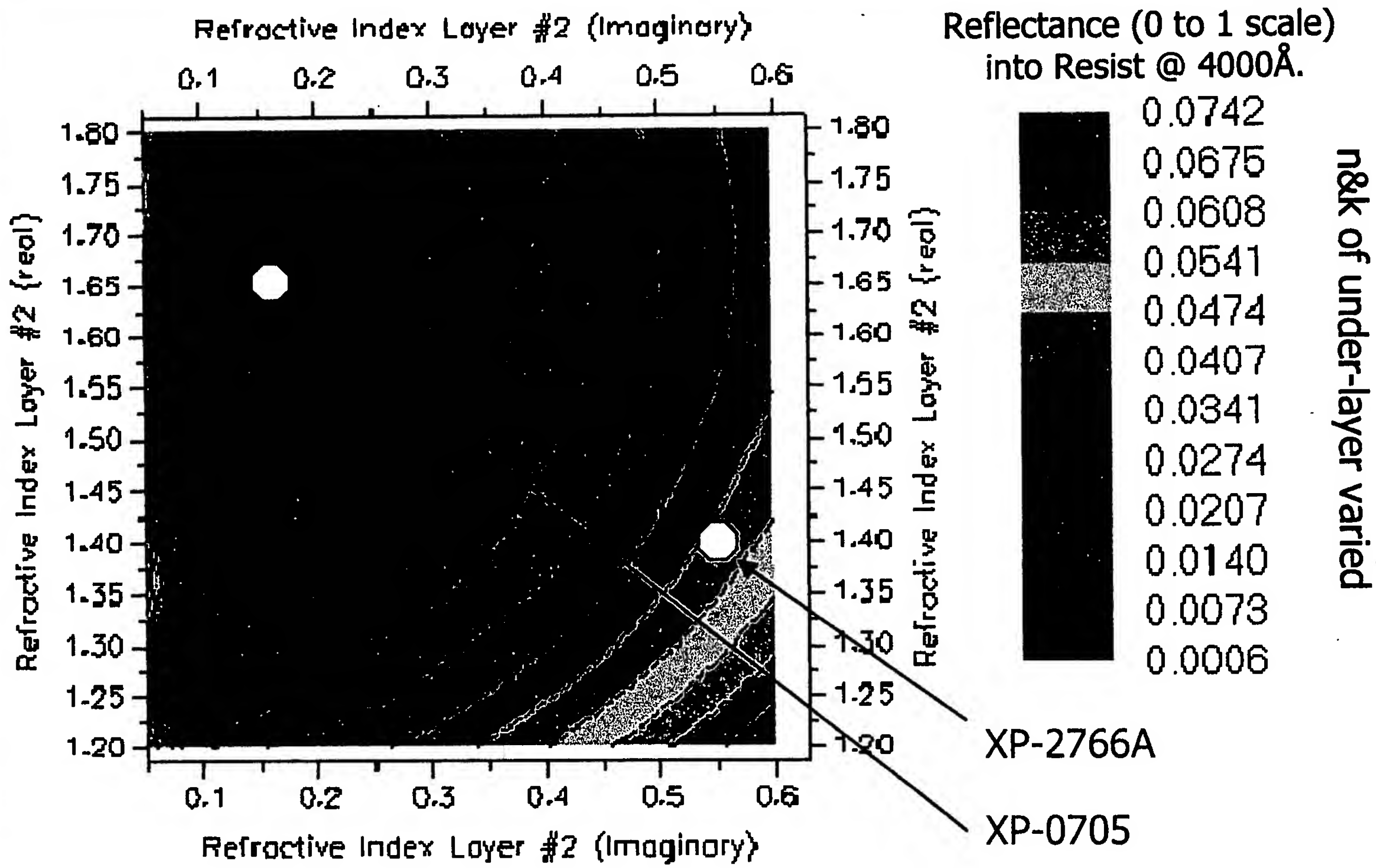
0.15	0.1	0.05	0	-0.05	-0.1	-0.15
Not open	84nm	88nm	87.5nm	88nm	84nm	Not open

SUB=8' Silicon
Bottom Layer: XP2766A
Cure = (250°C/60sec),
FT=5100Å
Top Layer=XP1646I
FT=1000Å
SB=90°C/60sec
EXP=ASML /1100 (0.75NA, σ= 0.45/0.7)
PEB=90°C/120sec

E_s=21mJ/cm²
%FL=0.25/μ

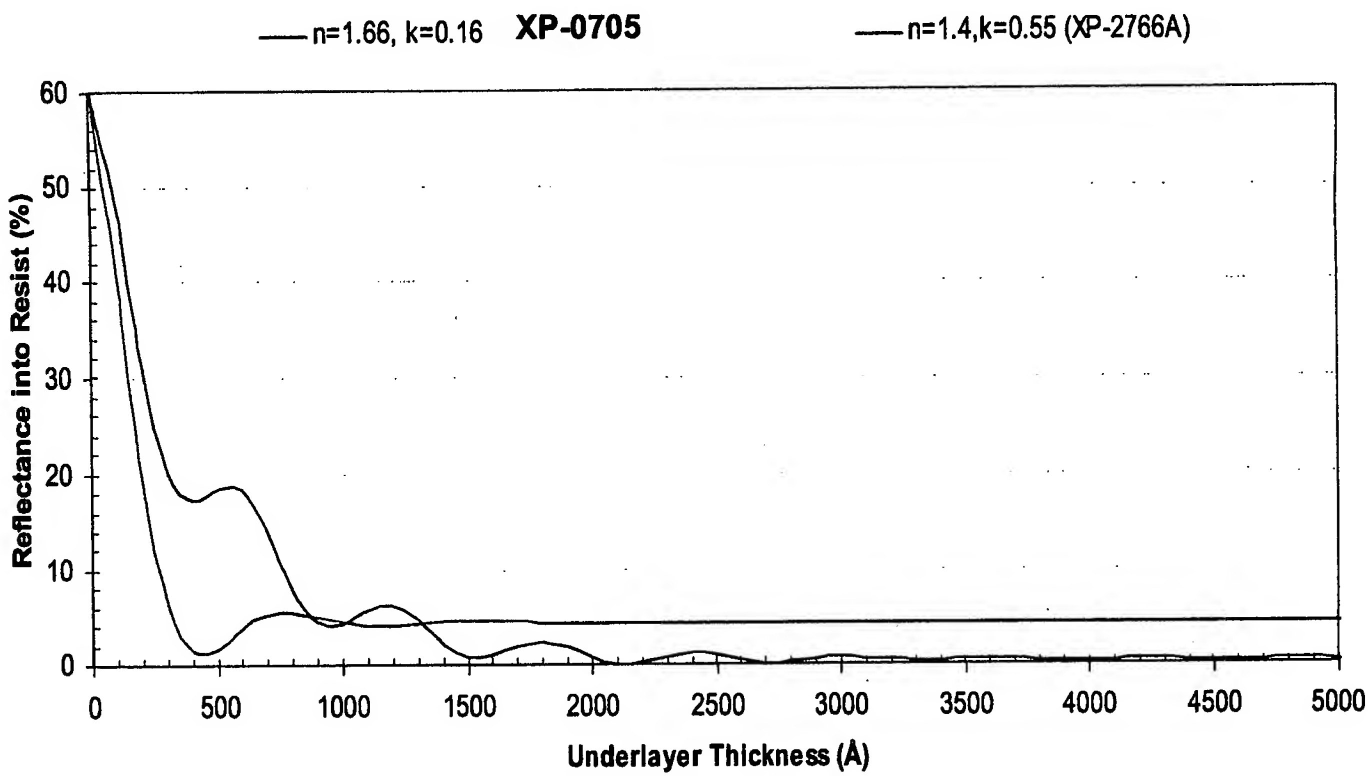
SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bi-layer: Underlayer Optimization
XP-1646 / 4000Å Underlayer / Si



ArF Bi-layer: Underlayer Optimization
XP-1646 / 4000Å Underlayer / Si

Simulation for XP-1646 / Underlayer/ Si
193nm, 0.75NA, Annular 0.4i / 0.8o

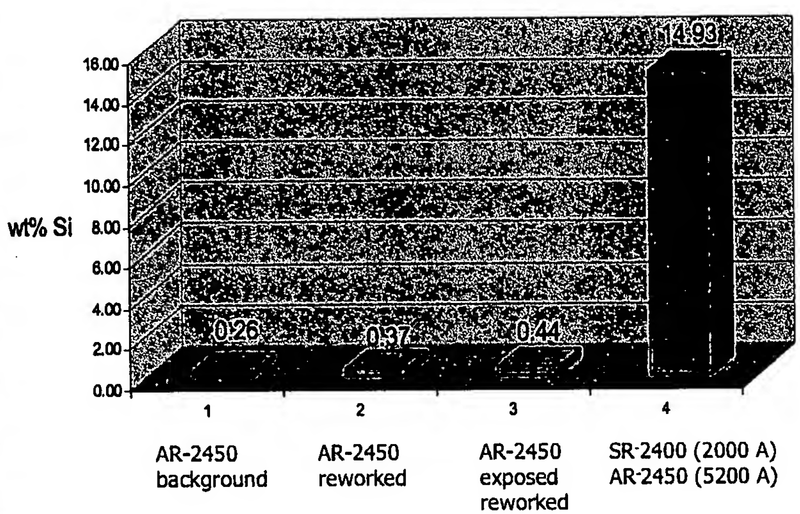


SHIPLEY
A ROHM AND HAAS COMPANY

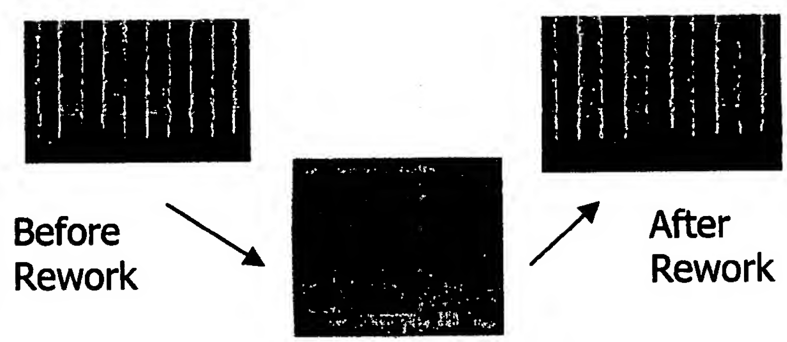
Top Layer Rework with "Standard Solvents"

Rework Process:
- KrF and ArF Top Layer Rework
- Soluble in Standard Resist Solvent
- Soluble in Standard EBR Solvents

ESCA Si Surface Analysis



Top Layer Rework SR2400



Reworked AR™2450

KrF Bilayer: Summary

SiBER

- State of the Art KrF SSQ Bilayer Platform
  - Highest Si Content of Any Commercial Bilayer System
  - Excellent etch resistance & Thin film imaging capability
  - No Outgassing of Si species (Si in the polymer backbone)
- Already Demonstrated Production Worthy by other IC manufacturers
- Demonstrated Control of LER, Iso-Dense Bias etc
- Commercial Products Available for BEOL and FEOL Applications
- Shipley KrF Bilayer Resist technology is capable of resolving 100nm features: L/S and Trenches
- Pattern Fidelity is retained through etch pattern transfer step – Allowing for high aspect ratio features at 100nm's and below

SHIPLEY
A ROHM AND HAAS COMPANY

ArF Bilayer: Summary

- Performance Summary: Sub 100nm Lithography Demonstrated
  - L/S 90 nm 1:1 (0.75 NA, ASML/1100)
  - Trench 90 nm 1:1 (0.75 NA, ASML/1100)
  - C/H 95 nm 1:1 (0.75 NA, ASML/1100)
  - C/H Super Dense 120/200 (0.75 NA, ASML/1100)
- SSQ Platform:
  - Tunable dissolution behavior
  - High Si Content > 10%
  - No Outgassing of Si
- ArF Bilayer Resists
  - UTR Silicon Resist Developed – 1000A
  - Bright-field and Dark-field being developed
  - Bottom Layer Developed, XP0705 and XP2766A

SHIPLEY
A ROHM AND HAAS COMPANY